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Change in vulnerability among older adults after hospital discharge: Does home health make a difference?

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Running Title: Change in Vulnerability After Hospital Discharge

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Abstract

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

Design: Secondary analysis of longitudinal data from a cohort study.

Setting, Participants: 834 older (≥ 65 years) patients hospitalized for acute coronary syndromes and/or acute decompensated heart failure who were discharged home with self-care or an HHC referral.

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

Results: At baseline, 44.4% of the participants were vulnerable at baseline. Compared with self-care (non-HHC-referred) patients (n=713), HHC-referred patients (n=121) were more vulnerable at baseline (66.9% vs. 40.3%) with delayed recovery in vulnerability in the initial 30 days (VES-13 change: -1.34 [95% C.I.: -2.07, -0.61], p<0.001), but had comparable improvement in vulnerability over the entire 90 days after hospital discharge. Baseline vulnerability and having an HHC referral accounted for 14%-16% of the variance in vulnerability change in the 90 days after hospital discharge, and patient characteristics (e.g., age, race [African American], depressive symptoms, and outpatient visits and hospitalizations in the past year) contributed another 6%.

Conclusions: Among older patients hospitalized for acute coronary syndromes and/or acute

decompensated heart failure, those referred to HHC were more vulnerable at baseline and had delayed recovery in vulnerability in the initial 30 days after discharge, but improved in vulnerability at 90 days after discharge at a similar degree as that in self-care patients. HHC seemed to facilitate post-discharge functional recovery in older hospitalized patients.

: vulnerability, frailty, functional decline, post-acute care, home health, older adults

Strengths and limitations of this study

1. This was the first study comparing prospective changes in vulnerability to functional decline for up to 90 days after hospital discharge among 834 older cardiac patients in different post-acute care options (self-care versus being referred to home health care [HHC]).
2. Follow-up rates were high, i.e., 94% at 30 days after discharge and 97% at 90 days after hospital discharge.
3. Potential confounders on HHC referral related to patient sociodemographic and clinical variables were controlled for using propensity score matching.
4. The measurement of vulnerability (Vulnerable Elders Survey [VES-13]) includes self-perceived health status and physical function but does not include an objective measure of vulnerability (e.g., gait speed). Because of the self-report nature of VES-13, subjects not able to communicate clearly were excluded.
5. 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 U.S. population,[1] yet they account for over 40% of hospitalizations in the U.S.[2] Cardiovascular disease (CVD) is the leading cause of hospitalization in the elderly[3] and is associated with complex self-care needs[4] and post-discharge 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 CVD[8] and is related to an increased risk for disability,[9] emergency department (ED) visits,[8] hospital complications and death.[10] In addition, vulnerability is dynamic and its level or severity can change in relation to time[11] and stressors, such as acute illness and hospitalization.[12] A vicious cycle is possible, in which a higher degree of baseline vulnerability increases the risk for hospitalization,[13] giving rise to further worsening of vulnerability.[8] However, few studies have quantified changes in vulnerability after hospital discharge and post-acute services that may modify this trajectory for older CVD patients.

In the U.S., half of older hospitalized patients in the U.S. are discharged to post-acute care that aims to facilitate functional recovery and prevent adverse outcomes.[14] In 2013, for example, the post-acute care sector in the U.S. incurred medical expenditure of 59.4 billion dollars.[15] Common U.S. post-acute 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 hospitalization, and 3) home-based Medicare home health care (HHC) services for older patients who do not need intensive physical rehabilitation yet are not able to recover independently (i.e., with self-care only).[14, 16] In particular, HHC is the fastest growing post-acute care modality in the U.S. that provides multi-disciplinary services to over one third of the

non-institutionalized older patients each year.[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 rehospitalization,[19] and delays nursing home placements[20] after hospital discharge in older adults. Medical expenditures for HHC users were also lower with an adjusted cost saving of $6,433 in the 365 days after hospital discharge.[21] As such, it seems that HHC provides efficient and cost-effective services to prevent post-discharge adverse outcomes.

However, evidence has also shown that patients do not benefit equally from post-acute care such as HHC, due to the variance in modifiable risk factors [22]. It is thus important that available 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 factors is vulnerability, which is found in over half of (54%-89.5%) of older hospitalized patients.[8, 12] However, no studies to date have examined how HHC affects post-discharge changes in vulnerability to functional decline among older adults. To fill this gap in knowledge, the following objectives were addressed in this study, including: 1) to compare the changes in vulnerability from baseline (i.e., prior to the event triggering the hospitalization) up to 90 days after hospital discharge in older patients with CVD who were discharged home with or without a referral to post-acute HHC; and 2) to examine factors associated with changes in vulnerability between each assessment point (i.e., prior to hospital admission [baseline], 30 and 90 days post discharge). We hypothesized 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 (10/2011-12/2015) from a large prospective study about older patients hospitalized for cardiac diseases.[citation blinded] Participants in this 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; 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 Institutional Review Board of the University. A detailed description of all study measures collected in the parent study is available elsewhere.[citation blinded]

Subjects in the current study reflect a subset of participants in the original study who were ≥65 years old, discharged home from the index hospitalization, and had vulnerability assessments at both baseline and 30 or 90-days after hospital discharge (N=834). The flow of eligibility screening, enrollment, 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

De-identified data from the large cohort study were used for this study with no direct involvement of or interaction with participants specifically in the design, recruitment, or conduct of this study.

Variables and Measures

The primary study outcome was vulnerability, as measured by the Vulnerable Elders Survey (VES-13). The VES-13 is a validated self-report measurement (VES-13), including items on age, self-reported health, ability to complete common physical tasks, and difficulties with (independent) activities of daily living (ADLs/IADLs). According to total VES-13 score, vulnerability was categorized in three categories, i.e., being not vulnerable (0-2), vulnerable (3-6), and extremely vulnerable (7-10).[7] The VES-13 has strong predictive validity (ROC curve 0.78) for long-term functional decline and mortality.[7, 9, 13, 23] 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.[24] Willingness to accept the HHC referral was confirmed with the patient.

Covariates for risk adjustment included: 1) demographic and socioeconomic variables: age, sex, race/ethnicity, education level, health literacy (3-item Brief Health Literacy Screen [BHLS]),[25] annual household income, difficulty paying bills, marital status, social support (ENRICHD Social Support Inventory [ESSI])[26]; and 2) health history variables: diagnosis of the index hospitalization (ACS and/or AHDF), comorbidity (Elixhauser index),[27] length of hospital stay, depressive symptoms (Patient Health Questionnaire-8 [PHQ-8]),[28] cognitive functioning (Short Portable Mental Status Questionnaire [SPMSQ]),[29] and previous utilization of health services (number of outpatient visits, ED visits, and hospitalizations 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 standardized 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).

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 summarize categorical variables. Due to skewness, continuous variables were summarized using the median and inter-quartile range (IQR) and were transformed to normal distributions or into meaningful ordinal categories (dummy coded) for inclusion in analyses with underlying parametric assumptions. Chi-square tests of independence and Mann-Whitney tests were used to compare patient variables for HHC-referred and non-HHC-referred (i.e., 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. Patients with VES-13 score at baseline and at least one follow-up time point (30-day and/or 90-day) were included in inferential analysis.

Three linear regression approaches were used to examine the effects of HHC referral on change in post-discharge VES-13 scores from baseline: 1) full model: HHC referral indicator and all covariates; 2) propensity model: HHC referral indicator and propensity score in lieu of the individual covariates; 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, i.e., the same covariates included in the full model. Each HHC patient was matched to a non-HHC patient with the closest propensity score (maximum caliper/difference=0.012). This process resulted in a sub-sample of 95 matched cases (total N=190) for the matched pairs analysis. The dependent variable

for each regression model was change in post-discharge VES-13 scores during the respective time-period (baseline to 30-days post-discharge, 30- to 90-days post-discharge, and baseline to 90-days post-discharge). 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 post-discharge, where VES-13 score at 30-days post-discharge 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 (e.g., 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) R2-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 hospitalization was 3 days (range: 1-25 days). Statistically significant differences existed between participants who were referred to HHC upon 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 (i.e., improved) to 39.2% at 30-days and 34.4% at 90-days post-discharge (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 post-discharge. In the non-HHC-referred group, the rate of vulnerability continued to decrease over the entire 90-day post-discharge 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 post-discharge vulnerability were well replicated among the three regression models. From baseline to 30-days post-discharge, while consistent with the covariate models ($p<0.001$), the effects observed in the propensity matched subsample were the strongest (95% C.I. for VES-13 change: -2.07 to -0.61 points). In other words, compared to patients not referred to HHC, the HHC-referred patients had

between a 0.6 and 2.1 point increase in VES-13 scores from baseline to 30-days post-discharge. Between 30- and 90-days post-discharge, 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, 95% C.I: +0.20 to +1.45, p=0.010). Figure 2 illustrates these 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 post-discharge) 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 (=0.12-0.14, $p<0.001$) and patients with more outpatient visits in the past 12 months (=0.08-0.10, $p<0.05$) had a greater increase in vulnerability. Patients with more hospitalizations in the past 12 months had a greater increase in vulnerability from baseline to 30-days post-discharge (=0.09, $p<0.05$). From 30-days to 90-days post-discharge, patients with depressive symptoms (=0.11, $p<0.01$) and those who were African-American (vs. Caucasians) had a greater increase in vulnerability (=0.08, $p<0.05$). Table 4 presents these results in details.

Discussion

To our knowledge, this is the first prospective study that examined post-discharge changes in vulnerability to functional decline among older hospitalized patients with CVD (ACS and/or ADHF), and compared post-discharge vulnerability changes between patients in different post-acute care options (self-care versus being referred to HHC). One principal finding in this study was that 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. Another key finding was that HHC seemed to have a positive effect on facilitating post-discharge improvement in vulnerability in older hospitalized patients, who reported more vulnerability prior to hospital admission. In particular, such an effect of HHC on vulnerability seemed to be related to the time points, i.e., the first 30 days after hospital discharge versus 30 to 90 days after hospital discharge.

Overall, participants showed higher levels of baseline vulnerability (44%) relative to outpatient community-dwelling older adults (32%).[8] Vulnerability was particularly prevalent among HHC-referred patients (67%), 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 activities of daily living.[7, 30]

Among patients who were referred to HHC, vulnerability first worsened in the first 30 days after hospital discharge, then gradually improved in the following 60 days. This finding confirms the dynamic nature of physical function related to vulnerability and physical frailty[11, 31-34] – a phenotype focused on objective and physiological changes that is closely intertwined with vulnerability to functional decline.[35, 36] As shown in the groundbreaking study by Gill et al.,[11] community-dwelling older adults experienced frequent transitions in frailty over a period of 54 months. Similar findings on transitions and changes in vulnerability and physical frailty were also reported in several longitudinal cohort studies with community-dwelling older adults,[31-33, 37] indicating potential for targeted interventions.

Particularly, in natural conditions without consideration of restorative interventions, community-dwelling older adults were more likely to experience an increase (rather than

decrease) in their functional decline, especially among patients with more intensive care needs.[38] As such, the high prevalence of baseline vulnerability among HHC-referred patients (67%) indicates that their natural trajectory of post-discharge functional decline would more likely be progressive (than improving), if no restorative or supportive services had been provided by post-acute care. However, in this study, HHC-referred patients demonstrated comparable improvement in vulnerability at 90 days after discharge as non-HHC referred patients (i.e., those with less vulnerability and fewer intensive care needs), after controlling for baseline vulnerability and potential confounders. This finding suggests that older hospitalized patients who were referred to receive HHC after hospital discharge seemed to have facilitated vulnerability improvement overall in the 90 days after hospital discharge.

The effect of HHC on post-discharge vulnerability improvement, however, seemed to be closely related to the timing of HHC. In the initial 30 days after hospital discharge, HHC-referred subjects had substantially more worsening in vulnerability than the non-HHC-referred group after controlling for baseline vulnerability and potential covariates. This difference in increased vulnerability (95% C.I. of changes in VES-13: 0.6-2.1 points) could translate to a higher likelihood of other poor outcomes, including 5-year functional decline,[13] in-hospital complications or death,[10, 39]and greater utilization of healthcare services. At face value, it seems that HHC is counter-productive for older hospitalized patients in the initial 30 days after discharge. However, this may be related to the timing and amount of HHC provided in the immediate post-discharge period, as the magnitude of HHC effect on vulnerability may be related to the intensity of HHC services (e.g., type and frequency of visits and other referrals by HHC providers). Recent evidence has shown that post-acute HHC, when provided within the first week after discharge, reduces the hazard for 30-day hospital readmission by 39%.[40] This

means that, for older hospitalized patients, timely provision of supportive care in the immediate post-discharge period is key to overall post-acute functional improvement over a longer time frame.

The amount of HHC is also related to its effect on post-discharge outcomes. For example, Medicare patients who received at least 22 days or four skilled nursing visits in HHC were 13% less likely to have rehospitalization in the 90 days after discharge from HHC[20] and spent eight months longer at home, thus delaying costly nursing home placement.[41] On the contrary, patients who did not receive enough HHC (as deemed by family members) were 1.8 times more likely to die in a nursing home.[21] Since the current study did not include measures of the timing (e.g., when HHC services were initiated) or amount of HHC (e.g., how many home visits of each involved discipline in HHC were provided after discharge, e.g., skilled nursing and physical or occupational therapy), it is unknown if the delayed improvement in vulnerability was due to late or inadequate HHC provided in the first week (or 30 days) after hospital discharge, or null effect of HHC on vulnerability changes in this period even with early and adequate HHC services.

To date, the effects of home-based care on improving functional decline and reducing unnecessary healthcare utilization have been noted in multiple studies.[22, 42, 43] However, these studies were conducted in different countries, where substantial differences exist in the eligibility for and delivery models of HHC.[22, 42, 43] For example, in the U.S., one has to be verified as homebound by a physician to be eligible for HHC,[24] and HHC is often provided by for-profit agencies (80%).[16] In countries with universal health insurance such as the United Kingdom, Denmark and Australia, preventive home-based services are included in the national health policy for all older adults with needs, regardless of homebound status.[44] Furthermore,

HHC in the U.S. is primarily utilized as a short-term post-acute care service.[14, 45] On average, a U.S. 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.[43] This suggests that participants in this study may not have not received enough post-acute 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.

Findings in this study support the importance of baseline vulnerability to longitudinal changes. Among community-dwelling older adults and recently injured older patients, baseline lack of functional (vulnerability) or physical reserve (frailty) is the predominant predictor of subsequent changes in physical function, ADL disability, and survival in the following 18 to 54 months.[11, 46, 47] Thus, interventions for vulnerable older adults should focus on maintaining current functional level and avoiding stressors (e.g., illness exacerbations and hospitalizations), as each episode of illness and hospitalization was associated with functional decline and loss of independence.[48-50] Older patients with a higher frequency of health care utilization 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

A major limitation is that this study was not originally designed to compare differences in post-discharge vulnerability changes among patients in different post-acute care settings, thus data on the timing, type and amount of post-acute care services (HHC) received by each

participant were not available. However, given the paucity of data on post-discharge changes in vulnerability among older patients in different post-acute care settings, findings in the current study should be of value. 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,[51] the mean of accumulated HHC service per patient per year in the U.S. is 315 days (S.D.= 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 include specific measures of HHC services (i.e., timing, frequency and type of services). Another limitation is that we focused on post-discharge vulnerability changes for 90 days after hospital discharge, yet recovery in vulnerability and physical function can last for years.[52] 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 hospitalization (baseline measure). Future studies should incorporate objective, performance-based measures of vulnerability and frailty (e.g., gait speed, hand-grip strength) to augment self-report measures.[53] Patients with visual, hearing, and significant cognitive impairment were excluded from this study, which limits the generalizability of findings. In addition, we used propensity score matching to control for observable confounding (i.e., frail patients may be more likely to have an HHC referral); however, there might be unmeasured confounding that was not controlled for using this analytical technique.

Conclusion

Nearly half of older patients hospitalized for cardiovascular diseases (ACS and/or ADHF) were vulnerable at baseline. Patients discharged home with an HHC referral, despite being more vulnerable to functional decline at baseline and having delayed recovery in vulnerability in the initial 30 days after discharge, improved in vulnerability at 90 days post-discharge at a comparable rate as their counterparts who were discharged home without an HHC referral. Future research should examine the visit pattern, frequency, and intensity of HHC to further enhance post-discharge vulnerability improvement in these patients, especially in the first 30 days after hospital discharge. While more research is needed, this finding suggests that HHC may facilitate post-discharge improvement in vulnerability in older patients.

Figure 1: Study Flow Diagram

Figure 2: Vulnerability categories at each time of assessment for a group referred to home health care propensity matched with a group not referred to home health care (n=95 per group)

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

Table 2: Vulnerability Percentages by Group and Assessment Time Points

Table 3. Effects of discharge home with home health care (HHC) referral on change in VES-13 scores.

Table 4: Association of patient characteristics with changes in vulnerability after controlling for initial VES- 13 scores and home health care (HHC) referral in linear regression

Table 1: Characteristics of the sample (n=834) by HHC referral groups*

Characteristics	Overall Sample (n=834)	Non-HHC referred (n=713)	HHC referred (n=121)	p-value
Demographic and Socio-Economic Status				
Age, mean (S.D.)	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 $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 (S.D.)	31.0 [28-33]	31.0 [28-33]	31.0 [26-33]	0.050
Health History				
Primary diagnosis at index hospitalization:				**<0.001**
ACS, % (N)	64.9% (541)	69.7% (497)	44 (36.4%)	
ADHF, % (N)	28.4% (237)	24.8% (177)	60 (49.6%)	
Both, % (N)	6.7% (56)	5.5% (39)	17 (14.0%)	
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)	601 (72.1%)	528 (74%)	73 (60.3%)	
Moderate to severe (10-24)	233 (27.9%)	185 (26%)	48 (39.7%)	
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**
Hospitalizations (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**

Note: BHLS= Brief Health Literacy Screen; ESSI= ENRICHD Social Support Inventory; PHQ=Patient Health Questionnaire-8; SPMSQ=Short Portable Mental Status Questionnaire.

Table 2: Vulnerability Percentages by Group and Assessment Time Points

HHC Referral Group	Vulnerability Categories (VES-13 score)	Baseline		30 days Post Discharge		90 days Post Discharge	
		% (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)	

Note: VES-13=Vulnerable Elders Survey-13

Table 3. Effects of discharge home with home health care (HHC) referral on change in VES-13 scores.

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

Note: "B" are raw regression weights; " " are standardized regression weights.

Table 4: Association of patient characteristics with changes in vulnerability after controlling for initial VES- 13 scores and home health care (HHC) referral in linear regression

Characteristics	Change Period		
	Base - 30 Days	30 - 90 Days	Base - 90 Days
VES-13 score (Baseline)	-0.54[a]		-0.51[a]
VES-13 score (30-days)		-0.50[a]	
Home health care (HHC) referral	0.16[a]	-0.07	0.05
Hospital Admission Variables			
Age	0.14[a]	0.12[a]	0.14[a]
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[c]	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[b]	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[b]	0.08[c]	0.09[c]
Hospitalizations (past 12 months)	0.09[c]	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: (Base VES-13, HHC referral) adjusted =0.15, $p < 0.001$,
(Patient factors) change=0.06, $p < 0.001$; Final model: =0.46, adjusted =0.19, $p < 0.001$
Change 90 days from 90 days: (30-day VES-13, HHC referral) adjusted =0.13, $p < 0.001$,
(Patient factors) change=0.06, $p < 0.001$; Final model: =0.43, adjusted =0.17, $p < 0.001$
Change 90 days from baseline: (Base VES-13, HHC referral) adjusted =0.14, $p < 0.001$,
(Patient factors) change=0.06, $p < 0.001$; Final model: =0.44, adjusted =0.18, $p < 0.001$
Note: [a] < 0.001, [b] < 0.01, [c] < 0.05; BHLS= Brief Health Literacy Screen; ESSI= ENRICHD Social Support Inventory; PHQ=Patient Health Questionnaire-8; SPMSQ=Short Portable Mental Status Questionnaire;

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Conflicts of Interests

The authors declare no conflicts of interest pertaining to this manuscript.

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Data Sharing Statement

There is no unpublished data, e.g., technical appendix, statistical code, and dataset, available that are relevant to this specific secondary analysis study.

Author Statement

JW was responsible for the design, analysis, drafting and revision of this manuscript.

MSD was responsible for the analysis and revision of this manuscript.

SPB was responsible for the design and revision of this manuscript.

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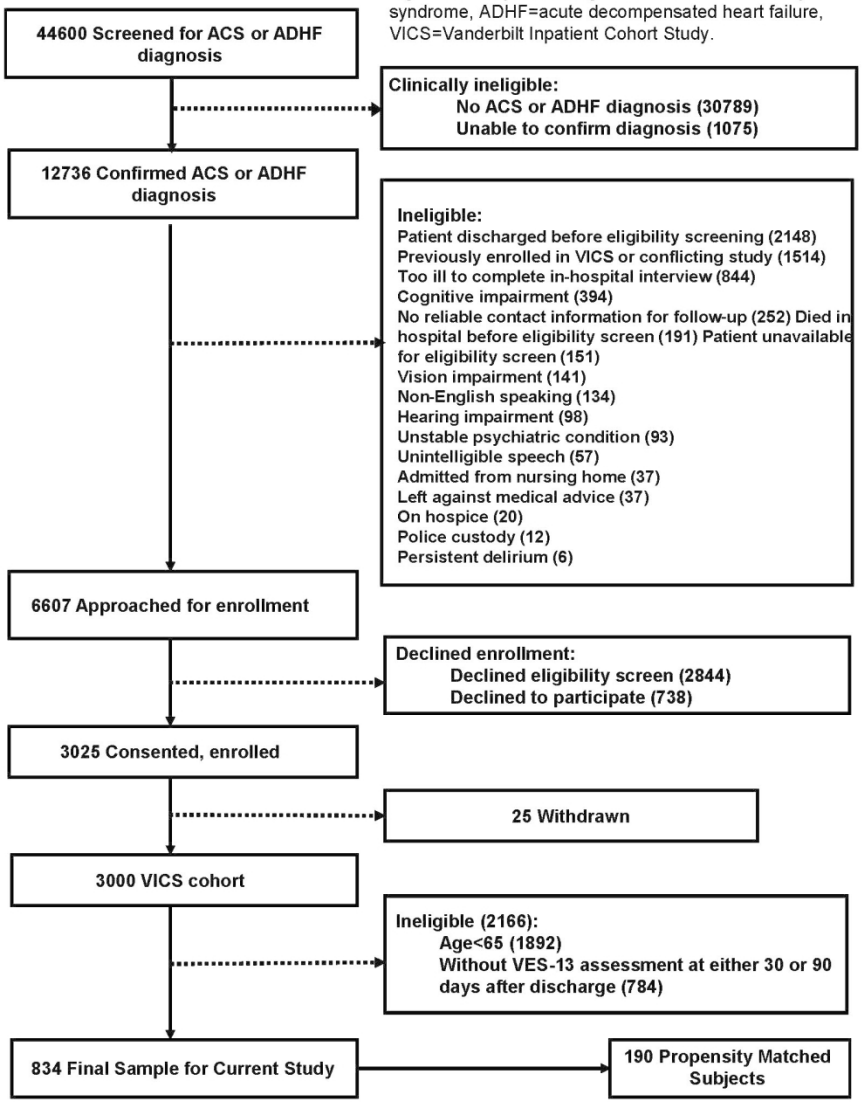

Figure 1: Study Flow Diagram. ACS=acute coronary syndrome, ADHF=acute decompensated heart failure, VICS=Vanderbilt Inpatient Cohort Study.

Figure 1

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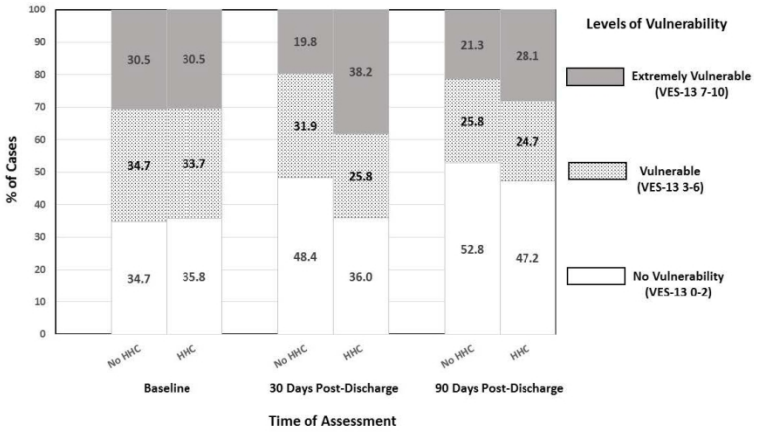
Figure 2. Vulnerability categories at each time of assessment for a group referred to home health care propensity matched with a group not referred to home health care (n=95 per group)



Note: This figure with box plots summarize the vulnerability categories (according to VES-13 scores) from the cases matched with propensity scores (n=190). Each column represents an assessment time point (left to right): baseline (prior to hospital admission), 30 days post-discharge, and 90 days post-discharge. Two bars are included in each column: left-not referred to HHC; right- referred to HHC. Horizontally from bottom up, each of the three colors/patterns respectively represents: not vulnerable, vulnerable, and extremely vulnerable. .

Figure 2: With legend/note

215x279mm (163 x 163 DPI)

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Changes in vulnerability among older cardiovascular patients in the first 90 days after hospital discharge: Role of home health referral

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Abstract

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

Design: Secondary analysis of longitudinal data from a cohort study.

Setting, Participants: 834 older (≥ 65 years) patients hospitalized 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 at baseline (prior to hospital admission) and 30- and/or 90-day after hospital discharge. Effects of HHC referral on post-discharge 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 pre-hospitalization 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 (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 post-discharge days, and 6% was attributed by patient age, race [African American], depressive symptoms, and outpatient visits and hospitalizations in the past year.

Conclusions: After adjusting for preceding vulnerability and covariates, older hospitalized cardiovascular patients 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 cardiovascular patients from 30 to 90 days after hospital discharge.

Keywords: vulnerability, frailty, functional decline, post-acute care, home health, older adults

Strengths and limitations of this study

1. This was the first study comparing prospective changes in post-discharge vulnerability for up to 90 days after hospital discharge among 834 older cardiovascular patients in different post-acute care options (self-care versus having a home health care [HHC] referral).
2. Follow-up rates were high, i.e., 97% at 30 days after discharge and 94% at 90 days after hospital discharge.
3. Potential confounders on HHC referral related to patient sociodemographic and clinical variables were controlled for using propensity score matching.
4. The measurement of vulnerability (Vulnerable Elders Survey [VES-13]) includes self-perceived health status and physical function but does not include an objective measure of vulnerability (e.g., gait speed). Because of the self-report nature of VES-13, subjects not able to communicate clearly were excluded.
5. 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 U.S. population,[1] yet they account for over 40% of hospitalizations in the U.S.[2] Cardiovascular disease is the leading cause of hospitalization in the elderly[3] and is associated with complex self-care needs[4] and post-discharge 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 time[11] and stressors, such as acute illness and hospitalization.[12] A vicious cycle is possible, where a higher degree of baseline vulnerability increases the risk for hospitalization,[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 post-acute services that may modify this trajectory for older cardiovascular patients.

In the U.S., half of older hospitalized patients are discharged to post-acute care that aims to facilitate functional recovery and prevent adverse outcomes.[14] In 2013, for example, the post-acute care sector in the U.S. incurred 59.4 billion dollars of medical expenditure.[15] Common U.S. post-acute 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 hospitalization, and 3) home-based Medicare home health care (HHC) services for older patients who do not need intensive physical rehabilitation yet are not able to recover independently (i.e., with self-care only).[14, 16] In particular, HHC is the fastest growing post-

acute care modality in the U.S. that provides multi-disciplinary services to over one third of the non-institutionalized 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 rehospitalization,[19] and delays nursing home placements.[20] Medical expenditures for HHC users were also lower with an adjusted cost saving of $6,433 in the 365 days after hospital discharge.[21] As such, it seems that HHC provides efficient and cost-effective services to prevent post-discharge adverse outcomes.

However, evidence has also shown that patients do not benefit equally from post-acute 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 hospitalized patients.[8, 12] To date, no studies have examined how HHC affects post-discharge changes in vulnerability to functional decline among older adults.

To fill this gap in knowledge, we conducted this study with the following objectives, including: 1) to compare the changes in vulnerability from baseline (i.e., prior to the event triggering the hospitalization) up to 90 days after hospital discharge in older patients with cardiovascular diseases who were discharged home with or without a referral to post-acute HHC; and 2) to examine factors associated with changes in vulnerability between each assessment point (i.e., prior to hospital admission [baseline], 30 and 90 days post discharge). We hypothesized 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 (10/2011-12/2015) from a large prospective study about older patients hospitalized for cardiovascular diseases.[citation blinded]

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; 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.[citation blinded]

Subjects in this study reflect a subset of participants in the original study who were ≥65 years old, discharged home from the index hospitalization, and had vulnerability assessments at both baseline and 30 or 90-days after hospital discharge (N=834). The flow of eligibility screening, enrollment, 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 de-identified 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 (VES-13). The VES-13 is a validated self-report measurement (VES-13), including items on age, self-reported health, ability to complete common physical tasks, and difficulties with (independent) activities of daily living (ADLs/IADLs). According to total VES-13 score, vulnerability was categorized in three categories, i.e., being not vulnerable (0-2), vulnerable (3-6), and extremely vulnerable (7-10).[7] The VES-13 has strong predictive validity (ROC curve 0.78) for long-term functional decline and mortality.[7, 9, 13, 23] 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.[24] Willingness to accept the HHC referral was confirmed with the patient.

Covariates for risk adjustment included: 1) demographic and socioeconomic variables: age, sex, race/ethnicity, education level, health literacy (3-item Brief Health Literacy Screen [BHLS]),[25] annual household income, difficulty paying bills, marital status, social support (ENRICHD Social Support Inventory [ESSI])[26]; and 2) health history variables: diagnosis of the index hospitalization (ACS and/or AHDF), comorbidity (Elixhauser index),[27] length of hospital stay, depressive symptoms (Patient Health Questionnaire-8 [PHQ-8]),[28] cognitive functioning (Short Portable Mental Status Questionnaire [SPMSQ]),[29] and previous utilization of health services (number of outpatient visits, ED visits, and hospitalizations 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 standardized 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).

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 summarize categorical variables. Due to skewness, continuous variables were summarized using the median and inter-quartile range (IQR) and were transformed to normal distributions or into meaningful ordinal categories (dummy coded) for inclusion in analyses with underlying parametric assumptions. Chi-square tests of independence and Mann-Whitney tests were used to compare patient variables for HHC-referred and non-HHC-referred (i.e., 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-day and/or 90-day) were included in inferential analysis.

Three linear regression approaches were used to examine the effects of HHC referral on change in post-discharge 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, i.e., 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 caliper/difference=0.012). This process resulted in a sub-sample of 95 matched cases (total N=190) for the matched pairs analysis. The dependent variable for each regression model was change in post-discharge VES-13 scores during the respective time-period (baseline to 30-days post-discharge, 30- to 90-days post-discharge, and baseline to 90-days post-discharge). 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 post-discharge, where VES-13 score at 30-days post-discharge 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 (e.g., 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) R2-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 hospitalization was 3 days (range: 1-25 days). Statistically significant differences existed between participants who were referred to HHC upon 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 (i.e., improved) to 39.2% at 30-days and 34.4% at 90-days post-discharge (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 post-discharge. In the non-HHC-referred group, the rate of vulnerability continued to decrease over the entire 90-day post-discharge 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 post-discharge vulnerability were well replicated among the three regression models -using both the entire sample and the propensity-matched pairs. From baseline to 30-days post-discharge, 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% C.I.= -2.07, -0.61], p<0.001). In other words, compared to patients not referred to HHC, the HHC-referred patients had a 0.6-2.1 point increase in VES-13 score (total 10 point) from baseline to 30-days post-discharge. Between 30- and 90-days post-discharge, 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% C.I.=0.20, 1.45], p=0.010). Figure 2 illustrates these 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 post-discharge) 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 hospitalizations in the past 12 months had a greater increase in vulnerability from baseline to 30-days post-discharge (*beta*=0.09, p<0.05). From 30-days to 90-days post-discharge, patients 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 post-discharge changes in vulnerability to functional decline among older hospitalized patients with

cardiovascular diseases (ACS and/or ADHF), and compared post-discharge vulnerability changes between patients in different post-acute 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 post-discharge improvement in vulnerability in older hospitalized 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 (i.e, worsening) in vulnerability than non-HHC-referred patients.

Overall, older post-discharge cardiovascular patients 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 activities of daily living.[7, 30]

Among patients who were referred to HHC, vulnerability first worsened in the first 30 days after hospital 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, 31-36] 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,[31-33, 37] indicating potential for targeted interventions.

Second, despite the recent hospitalization, older cardiovascular patients still improved in vulnerability to a degree that was lower (i.e., better) than their pre-hospitalization baseline. In natural conditions without interventions, community-dwelling older adults are more likely to increase (rather than decrease) in their functional decline.[38] As such, the high prevalence of baseline vulnerability among HHC-referred patients (67%) indicates that their natural trajectory of post-discharge 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 pre-hospitalization baseline (Covinsky et al., 2003), there is still room for functional improvement with targeted and intensive post-acute services. Baseline vulnerability and physical frailty can be used to identify patients who are likely to respond (or not) to certain post-acute services.

Third, the comparison between HHC-referred and non-HHC-referred patients (Table 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 decline[13] and a 53% higher likelihood of in-hospital complications or death.[10, 39]. In fact, vulnerbaility worsening in the first 30 days after hospital discharge may be the reason why HHC-referred heart failure patients had higher rates of 30-day

readmission and mortality after hospital discharge compared to their propensity score-matched non-HHC-referred counterparts.[40]

This result is intriguing, because at face value, it seems that HHC is counter-productive for older hospitalized patients in the initial 30 days after discharge. However, the impact of HHC on post-discharge vulnerability change may be related to the timing and visit intensity of HHC services provided for each patient. Recent evidence has shown that post-acute HHC, when provided within the first week after discharge, reduces the hazard for 30-day hospital readmission by 39%.[41] This means that, for older hospitalized patients, timely provision of supportive care in the immediate post-discharge period is key to overall post-acute functional improvement.

The intensity of HHC is also critical to its effect on vulnerability and outcomes such as rehospitalization. Medicare patients who received at least 22 days of HHC or four skilled nursing visits were less (13%) likely to be rehospitalized at 90 days after discharge from HHC.[20] In addition, patients who received at least two months of HHC spent eight months longer at home before nursing home placement, compared with those who received no or shorter duration of HHC.[42] 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 (e.g., when HHC services were provided) or visit intensity of HHC (e.g., 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 utilization have been noted in multiple studies.[22, 43, 44] However, these studies were conducted in different countries, where substantial differences exist in the eligibility for and delivery models of HHC.[22, 43, 44] For example, in the U.S., one has to be verified as homebound by a physician to be eligible for HHC,[24] and HHC is often provided by for-profit agencies (80%).[16] In countries with universal health insurance such as the United Kingdom, Denmark and Australia, preventive home-based services are included in the national health policy for all older adults with needs, regardless of homebound status.[45] Furthermore, HHC in the U.S. is primarily utilized as a short-term post-acute care service.[14, 46] On average, a U.S. 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.[44] This suggests that participants in this study may not have not received enough post-acute 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, 47, 48] Thus, interventions for vulnerable older adults should also focus on maintaining current functional level and avoiding stressors (e.g., illness exacerbations and hospitalizations), as each episode of illness and hospitalization was associated with functional decline and loss of independence.[49-51] Older patients with a higher frequency of health care

utilization 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 post-discharge vulnerability changes among patients in different post-acute care settings. However, given the paucity of data on post-discharge changes in vulnerability among older patients in different post-acute 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 (e.g., 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 post-discharge 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,[52] the mean of accumulated HHC service per patient per year in the U.S. is 315 days (S.D.= 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 randomized control design and include specific measures of HHC services (i.e., timing, frequency/intensity and type of services). Second, we focused on post-discharge vulnerability changes for 90 days after hospital discharge, yet recovery in vulnerability and physical function can last for years.[53] 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 hospitalization (baseline measure). Future studies should incorporate objective, performance-based measures of vulnerability and frailty (e.g., gait speed, hand-grip strength) to augment self-report measures.[54] 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 generalizability of findings. However, sample characteristics (i.e., 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 [citation blinded], 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 hospitalized cardiovascular patients were vulnerable at pre-hospitalization baseline. Patients discharged home with an HHC referral, despite being more vulnerable at pre-hospitalization 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 (i.e., better) than the pre-hospitalization baseline. Future research should examine how the pattern, frequency, and intensity of HHC services affect post-discharge vulnerability improvement in older cardiovascular patients. While more research is needed, this finding

suggests that HHC may facilitate post-discharge improvement in vulnerability in older cardiovascular patients from 30 to 90 days after hospital discharge.

Figure 1: Study Flow Diagram

Figure 2: Vulnerability categories at each time of assessment for a group referred to home health care propensity matched with a group not referred to home health care (n=95 per group)

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

Table 2: Vulnerability Percentages by Group and Assessment Time Points

Table 3. Effects of discharge home with home health care (HHC) referral on change in VES-13 scores.

Table 4: Association of patient characteristics with changes in vulnerability after controlling for initial VES- 13 scores and home health care (HHC) referral in linear regression

Table 1: Characteristics of the sample (n=834) by HHC referral groups*

Characteristics	Overall Sample (n=834)	Non-HHC referred (n=713)	HHC referred (n=121)	p-value
Demographic and Socio-Economic Status				
Age, mean (S.D.)	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 $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 (S.D.)	31.0 [28-33]	31.0 [28-33]	31.0 [26-33]	0.050
Health History				
Primary diagnosis at index hospitalization:				**<0.001**
ACS, % (N)	64.9% (541)	69.7% (497)	44 (36.4%)	
ADHF, % (N)	28.4% (237)	24.8% (177)	60 (49.6%)	
Both, % (N)	6.7% (56)	5.5% (39)	17 (14.0%)	
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)	601 (72.1%)	528 (74%)	73 (60.3%)	
Moderate to severe (10-24)	233 (27.9%)	185 (26%)	48 (39.7%)	
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**
Hospitalizations (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**

Note: BHLS= Brief Health Literacy Screen; ESSI= ENRICHD Social Support Inventory; PHQ=Patient Health Questionnaire-8; SPMSQ=Short Portable Mental Status Questionnaire.

Table 2: Vulnerability Percentages by Group and Assessment Time Points

HHC Referral Group	Vulnerability Categories (VES-13 score)	Baseline		30 days Post Discharge		90 days Post Discharge	
		% (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)	

Note: VES-13=Vulnerable Elders Survey-13

Table 3. Effects of discharge home with home health care (HHC) referral on change in VES-13 scores.

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

Note: "B" are raw regression weights; "*beta*" are standardized regression weights.

Table 4: Association of patient characteristics with changes in vulnerability after controlling for initial VES- 13 scores and home health care (HHC) referral in linear regression

Characteristics	Change Period		
	Base - 30 Days	30 - 90 Days	Base - 90 Days
VES-13 score (Baseline)	-0.54[a]		-0.51[a]
VES-13 score (30-days)		-0.50[a]	
Home health care (HHC) referral	0.16[a]	-0.07*	0.05
Hospital Admission Variables			
Age	0.14[a]	0.12[a]	0.14[a]
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[c]	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[b]	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[b]	0.08[c]	0.09[c]
Hospitalizations (past 12 months)	0.09[c]	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: (Base 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=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=0.43, adjusted R^2=0.17, p < 0.001
Change 90 days from baseline: (Base 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=0.44, adjusted R^2=0.18, p < 0.001
Note: [a]$p < 0.001$, [b]$p < 0.01$, [c]$p < 0.05$; *P=0.059; BHLS= Brief Health Literacy Screen; ESSI= ENRICHD Social Support Inventory; PHQ=Patient Health Questionnaire-8; SPMSQ=Short Portable Mental Status Questionnaire;

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Conflicts of Interests

The authors declare no conflicts of interest pertaining to this manuscript.

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Data Sharing Statement

There is no unpublished data, e.g., technical appendix, statistical code, and dataset, available that are relevant to this specific secondary analysis study.

Author Statement

JW was responsible for the design, analysis, drafting and revision of this manuscript.

MSD was responsible for the analysis and revision of this manuscript.

SPB was responsible for the design and revision of this manuscript.

CAM was responsible for the design and revision of this manuscript.

SFS was responsible for the design and revision of this manuscript.

SK was responsible for the design and revision of this manuscript.

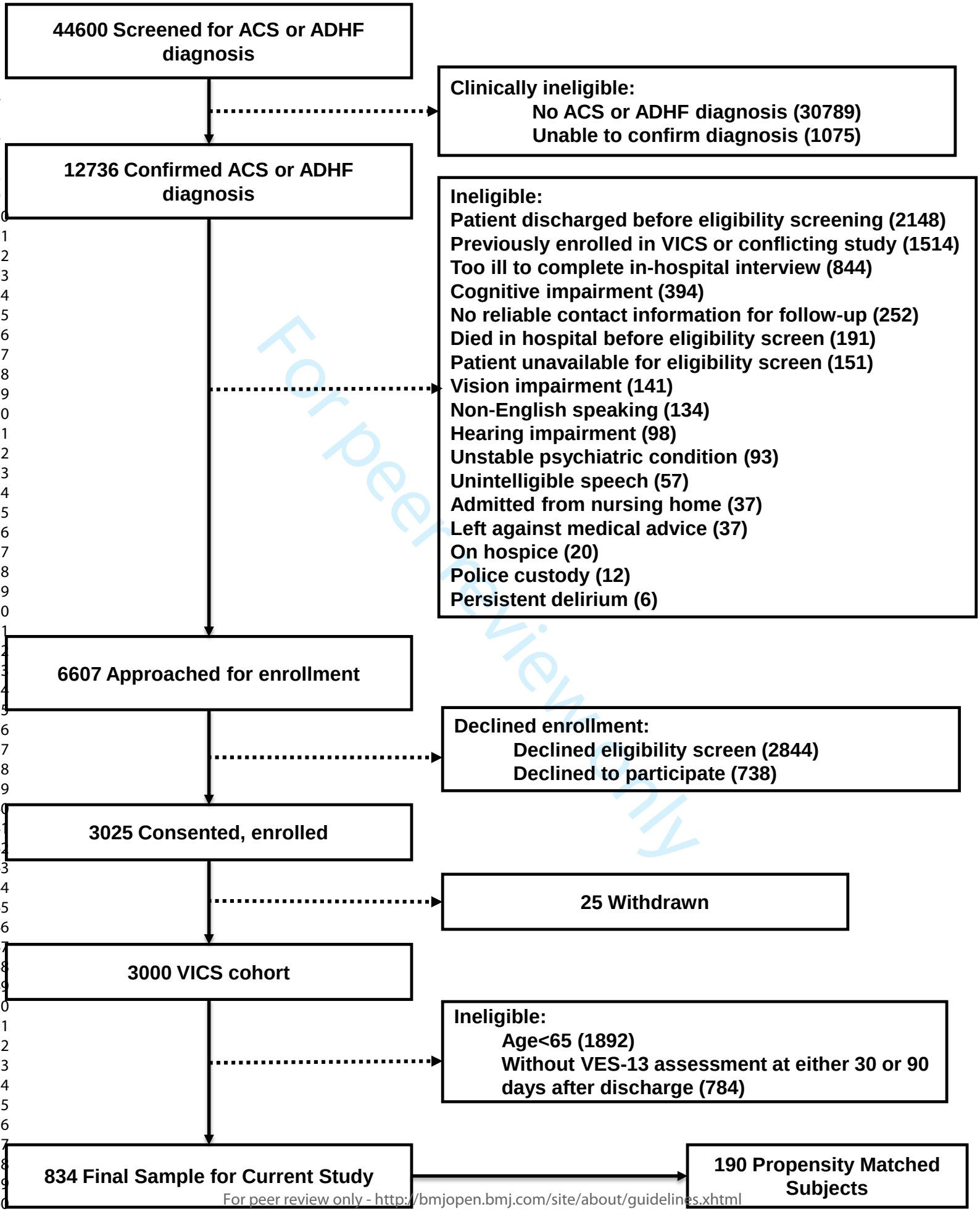
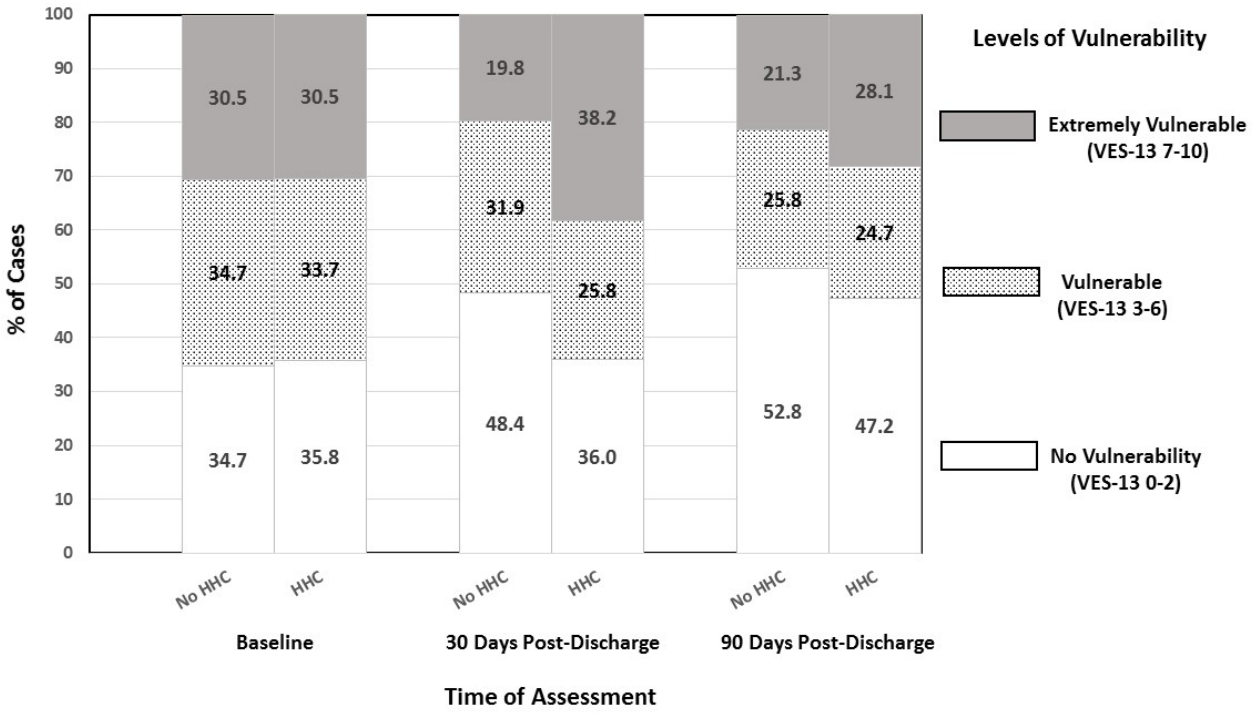


Figure 2. Vulnerability categories at each time of assessment for the propensity matched groups.



STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

	1	( ) Indicate the study's design with a commonly used term in the title or the abstract	addressed in " title"
		( ) Provide in the abstract an informative and balanced summary of what was done and what was found	addressed in "abstract"
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	page 1, 2
Objectives	3	State specific objectives, including any prespecified hypotheses	line 39-46
Study design	4	Present key elements of study design early in the paper	line 48-50
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	line 52-66
Participants	6	( ) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	line 52-58
		( ) For matched studies, give matching criteria and number of exposed and unexposed	propensity score matching: line 113-118
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	line 71-96
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	- dependent variable: line 72-79 - independent variable: 80-83 - covariates: line 84-96
Bias	9	Describe any efforts to address potential sources of bias	- propensity score matching (line 113-118) - discussion of potential selection bias and residual bias of propensity score matching (line 304-313) - discussion of variance in HHC visit intensity (line 233-240, line 286-296)
Study size	10	Explain how the study size was arrived at	Figure 1: inclusion diagram Text: (line 61-66)
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	- variables: line 71-95; - HHC referral: line 20-83 - propensity score matching: line 113-118
Statistical methods	12	( ) Describe all statistical methods, including those used to control for confounding	line 97-134
		( ) Describe any methods used to examine subgroups and interactions	no interaction was examined
		( ) Explain how missing data were addressed	line 105-108
		( ) If applicable, explain how loss to follow-up was addressed	line 63-66, 105-108
		(_) Describe any sensitivity analyses	Not conducted. 1) follow-up rates were high (97% at 30 days after discharge and 94% at 90 days after hospital discharge); 2) A comparison on sample characteristics and outcome variables between sample used

			for this study and sample and sample in the parent study revealed that they were similar in both. (line 306-311)
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Figure 1, line 61-66
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	line 136-145
		(b) Indicate number of participants with missing data for each variable of interest	line 104-108
		(c) Summarise follow-up time (eg, average and total amount)	N/A: set follow-up time points (30 days and 90 days after hospital discharge)
Outcome data	15*	Report numbers of outcome events or summary measures over time	line 151-158
Main results	16	( ) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Table 2, 3, 4
		( ) Report category boundaries when continuous variables were categorized	N/A
		( ) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	Use of 30 and 90 days after hospital discharge as the time period for translating results
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	N/A
Key results	18	Summarise key results with reference to study objectives	line 183-193
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	line 280-313
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	Throughout discussion, e.g., line 200-232
Generalisability	21	Discuss the generalisability (external validity) of the study results	line 304-311
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	"Funding Statement"

*Give information separately for exposed and unexposed groups.