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Original Study

Inverse Dose-Response Relationship Between Home Health Care Services and Rehospitalization in Older Adults

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A B S T R A C T

Objectives: (1) To examine the impact of specific services [skilled nursing (SN), physical therapy (PT), occupational therapy (OT), and home health aide (HA)] in Medicare-certified home health care (HHC) on subsequent rehospitalization among older patients during a 60-day HHC episode and (2) to test the moderating effect of functional limitation on these services.
Design: Secondary analysis of data from the Outcome and Assessment Information Set (OASIS) and HHC administrative records of a statewide not-for-profit HHC agency from January 1, 2016, to December 31, 2016.
Setting and Participants: Participants were ≥65 years old and were admitted to HHC within 48 hours of hospital discharge.
Measures: Outcome was time to rehospitalization during the 60-day HHC episode (ie, number of days). Independent variables were visit intensity (number of visits/week) of SN, PT, OT, and HA, respectively. Functional limitation was measured by a composite score generated from 9 OASIS items on physical function. Multivariate Cox Proportional hazard analyses were conducted. Subgroup analysis (high vs low functional limitation) was conducted to examine the moderating effect of functional limitation on specific HHC services. Ad hoc analysis was conducted to examine potential interaction between specific HHC services that were significantly related to rehospitalization.
Results: The sample included 1377 participants, among whom 11.5% were rehospitalized during the 60-day HHC episode. At the threshold dose of 1 PT or 2 SN visits/week, higher visit intensity significantly reduced the hazard of rehospitalization in these patients by up to 82% for PT (2.30 visits/week; hazard ratio [HR] = 0.18, P value < .001) and 48% for SN visits (2.51 visits/week; HR = 0.52, P value < .05). The effect of PT on reducing the risk of rehospitalization was more pronounced in patients with low versus high functional limitation (2.30 visits/week, HR = 0.08 vs 0.24, both $P < .001$). SN was only effective in reducing the hazard of rehospitalization in the low functional limitation group (1.70 visits/week, HR = 0.41, $P < .05$; 2.51 visits/week, HR = 0.29, $P < .05$), but not in the high functional limitation group ($P > .05$ at all intensity levels). Visit intensity of HA or OT was not significantly related to rehospitalization.
Conclusions/Relevance: At a threshold of 1 PT visit or 2 SN visits/week, HHC lowered the risk of rehospitalization in older patients by up to 82% and 48%, respectively. Both PT and SN were more effective in avoiding rehospitalization in patients with low functional limitation than in those with high functional limitation. Older patients should receive enough HHC services (especially PT and SN) to avoid rehospitalizations with consideration of their functional limitation.
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The authors declare no conflicts of interest.

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Older patients are at risk for postdischarge functional decline[1] and rehospitalizations, which occur in one-third of Medicare patients within 90 days after hospital discharge and are mostly (90%) unplanned.[2] Every year, 3.3 million rehospitalizations occur in the United States, costing $41.3 billion[3] and potentially 1% to 3% of annual Medicare reimbursement as penalties.[4] To prevent unplanned rehospitalization, older patients with high medical complexity and acuity are referred to as post-acute services.[5] Medicare-certified home health care (HHC)—the largest provider of home-based post-acute care—serves more than one-third of noninstitutionalized older Americans after hospital discharge.[6] Patients who qualify for HHC are homebound (ie, leaving home is medically contradicted for the patient or would require substantial assistance[7,8]) and have multiple medical conditions, thus requiring comprehensive HHC services, including skilled nursing (SN), physical therapy (PT), occupational therapy (OT), and health aides (HA), to meet their clinical, functional, and psychosocial needs to prevent rehospitalization.[8]

Emerging evidence[9–14] has shown that, overall, HHC improves physical function[15] and reduces healthcare cost,[11] for which the "dosing" of specific HHC services is likely the key. Medicare patients receiving 22 days of HHC or 4 SN visits were 13% less likely to be rehospitalized within 90 days after HHC discharge, compared to those receiving a shorter HHC stay or fewer SN visits.[10] Patients receiving ≥2 months of HHC also spent 8 months longer at home prior to nursing home placement.[12]

Despite these promising findings, evidence-based research in HHC is limited in that only 1 study has examined the minimally effective doses ("threshold") of HHC for preventing rehospitalization (total duration [22 days] and SN visits [4]).[10] It is unknown if a dose-response relationship exists between rehospitalization and other HHC services (PT, OT, and HA) and what the threshold is for each to prevent rehospitalization. Although most HHC agencies conduct an initial patient assessment (eg, with the Outcome and Assessment Information Set [OASIS]), it is unclear if a person-centered care approach is used to maximize benefits (eg, reducing rehospitalization)[16,17] and minimize costs. Person-centered care considers patient needs regarding individual capabilities, preferences, and risk factors for adverse outcomes, and tailors specific services to meet these needs,[18] which is foundational to implement "precision HHC" in the future. One domain of relevance to HHC is functional limitation, as it is related to both rehospitalization[19] and the focus of HHC.[15]

The objectives of this study were to examine (1) the impact of specific HHC services (SN, PT, OT, or HA) on subsequent rehospitalization among older patients during a 60-day HHC episode and (2) the moderating effect of functional limitation on these HHC services. We hypothesized that (1) for each HHC service, a higher visit intensity is related to a lower risk of rehospitalization with a threshold; and (2) adjusting for visit intensity, the effect of each HHC service on reducing the risk of rehospitalization is smaller among participants with a higher level of functional limitation than those with a lower level of functional limitation.

Conceptual Model

We adapted the Andersen Behavioral Model (ABM) of health services use[20] to guide the design and analysis of this study (Figure 1). ABM is extensively used in health services research[21] to examine how "system and environment," "patient characteristics," and "health behaviors" affect "outcomes." ABM suggests that one's health service use depends on his or her predisposition to use services (eg, demographic status, social structure, health beliefs), factors that enable or impede service use (eg, personal/family/community resources), and the need for services (eg, clinical and functional factors). The "system and environment" section was not included in this study, as related variables were not available.

Methods

Study Design

This was a secondary analysis of data from the OASIS and administrative records (January 1, 2016–December 31, 2016) of a non-for-profit HHC organization in New York with more than 700 clinicians that provides more than 600,000 home visits annually.

Study Population and Sample

The study population was older post-discharge patients in HHC. Inclusion criteria included (1) age ≥65 years; (2) HHC admission within 48 hours since hospital discharge; and (3) receiving ≥1 HHC visit in the 60-day episode. Excluded were patients with chronic debilitating conditions who may have a different response to HHC and different goals of care from general posthospitalization older adults. These conditions, as assessed by 6 OASIS admission diagnosis items (M1021, M1023b-f), included (1) severe mental, physical, or neurologic diseases, including Alzheimer's disease, schizophrenia, bipolar or

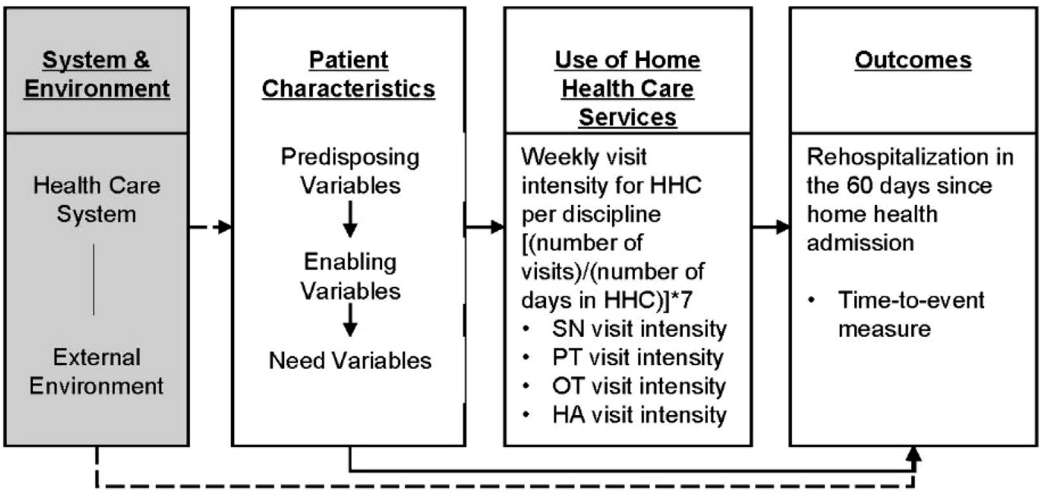

Fig. 1. Adapted Andersen behavioral model.

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anxiety diagnosis, quadriplegia, paraplegia, cerebral palsy, neuromuscular disorders such as muscular dystrophy, multiple sclerosis, ataxia, and amputation and (2) malignant diseases within the previous 5 years (except for minor skin cancer) (see Appendix). This study was approved by an institutional review board.

Variables and Measures

Variables included (1) outcome—rehospitalization; (2) independent variables—use of HHC services; and (3) covariates—patient characteristics. Data were extracted from administrative records (use of HHC services) and OASIS (rehospitalization, patient characteristics).

OASIS is a Medicare-required national data set to measure patient outcomes, that is, rehospitalization.[22] OASIS assessments include patient demographic status, living arrangement, medical diagnoses, physical function, mental health, and informal caregiving.[23] These assessments are conducted by registered nurses and licensed therapists (ie, on physical function). OASIS has sufficient validity (coefficient alpha 0.86-0.91)[24] and reliability (interrater $k \geq 0.60$),[25] especially in the domains of physical and cognitive function.

Outcome: Rehospitalization

Rehospitalization during the 60-day HHC episode (M2410) was operationalized as a time-to-event measure, that is, number of days from HHC admission to rehospitalization.

Independent Variables: Use of HHC (Visit Intensity)

Independent variables were the discipline-specific weekly visit intensities (ie, number of visits/week) of (1) SN, (2) PT, (3) OT, and (4) HA—calculated as [(total number of visits)/(number of days receiving HHC)] $\times$ 7. As a robust measure of HHC dosing,[15] this approach avoids mixing the effects of different HHC services on rehospitalization—an analytical advantage over the aggregated dosing method using total duration or total number of visits from all disciplines. Visit intensity of each discipline was categorized into quartiles in data analysis.

Covariates: Patient Characteristics

Patient characteristics included 3 groups: (1) *predisposing factors*—age (years), sex (female/male), race/ethnicity (Caucasian/African American/Other), and marital status (married/not married), obesity (yes/no), smoking (past or present: yes/no); (2) *enabling factors*—living arrangement (alone/with others), health insurance [Medicare and Medicaid dual eligibility (yes/no)], daily caregiver assistance (yes/no); and (3) *need factors*—number of days during index hospitalization, specific diagnoses (ie, hypertension, heart failure, diabetes, osteoarthritis, and chronic obstructive pulmonary disease [COPD]—each coded as yes/no based on OASIS diagnoses [M1021, M1023b-f]), taking $\geq$10 medications (yes/no), mild/moderate cognitive impairment (yes/no), daily pain that interferes with ADL/IADL (yes/no), depressive symptoms (physician-prescribed depression intervention because of a diagnosis of depression or a Patient Health Questionnaire–9 score of $\geq$6 (yes/no)], and self-reported exhaustion (yes/no).

Moderator: Functional Limitation

Functional limitation was measured by 9 OASIS admission items, each on a Likert scale of 0 to n (a larger value indicates more limitation). The 9 ADL items include grooming (0-3), dressing upper/lower body (each 0-3), bathing (0-6), toilet transferring (0-4), toilet hygiene (0-3), transferring (0-5), ambulation (0-6), and eating (0-5). Raw score of each item was divided by n to generate a standardized score (0-1), then summed into a composite score (range: 0-9). This composite score is sensitive in detecting individual variance in functional limitation.[15] In subgroup analysis, the median of this composite score (6.6) was used to categorize the sample into high versus low functional limitation group.

Statistical Analysis

No missing values were found when visually inspecting raw data. Descriptive statistics were used to summarize sample characteristics as means (standard deviations [SDs]) for continuous variables and frequency (% [N]) for categorical variables. After ensuring the proportionality assumption (Scaled Schoenfeld residual analysis, global test, $P > .05$), the relationship between HHC visit intensity and time-to-event measure of rehospitalization was examined by survival analyses (ie, Cox proportional hazards model). All statistical analyses were conducted using Stata 15.1 (College Station, TX).

Analysis for hypothesis 1

Bivariate analysis was first conducted between each independent variable or covariate and rehospitalization in Cox proportional hazard models. Variables significantly associated with rehospitalization in bivariate analyses ($P < .2$) and covariates selected a priori in the ABM model were added to the multivariate Cox proportional hazards model (model 1). If more than 1 service was related to rehospitalization, then ad hoc analysis was performed to examine the additive effects of the services on the hazard of hospitalization. We categorized the dose of a service into low (<threshold) and high ($\geq$threshold) and added the interaction term (service 1_high*service 2_high) to model 1.

Analysis for hypothesis 2

First, bivariate analyses were conducted, respectively, between functional limitation and HHC visit intensity and between functional limitation and rehospitalization. Results showed that functional limitation was related to both HHC intensity and rehospitalization, thus meeting the prerequisite of moderation testing. Second, subgroup analysis of patients with high versus low functional limitation was conducted by repeating analyses for hypothesis 1 in the 2 groups.

Results

Sample Characteristics

The sample included 1377 patients with an average age of 79 who were mostly Caucasians and living with others at home. Approximately half were married and female. The majority (88%) of participants had 6 documented medical diagnoses (maximum number allowed in OASIS), and 60% took $\geq$10 medications. The most common medical diagnoses included hypertension (72%), osteoarthritis (24%), heart failure (22%), diabetes (22%), and COPD (11%). On average, patients spent 5 days during the index hospitalization before HHC admission. More than 70% had mild/moderate cognitive impairment (77%) and daily interfering pain (71%), and some reported exhaustion (47%) and depressive symptoms (22%). The median functional limitation score was 6.6 for the entire sample, with a mean of 5.6 in the low functional limitation group and 7.2 in the high functional limitation group.

During the 60-day episode, 68% participants received both SN and PT, 27% received SN only, and 5% received PT only; 23% received OT and 8% received HA. The median number of visits/week was 1.5 for SN, 0.9 for PT, and 0 for OT and HA. From the lowest to the highest quartile of visit intensity, the median number of visits/week for each discipline was (1) SN: 0.30, 1.21, 1.70, 2.51; (2) PT: 0, 0.54, 1.36, 2.30; (3) OT: 0, 0, 0, and 0.47; and (4) HA: 0, 0, 0, and 0.47.

During the 60-day episode, rehospitalization occurred in 11.5% of the participants at a median of 20 days since HHC admission (mean: 26, range: 10–43). Compared with nonrehospitalized patients,

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rehospitalized patients were more likely to have heart failure, COPD, or osteoarthritis; take ≥10 medications; have had a longer hospital stay before HHC admission; and have higher rates of exhaustion, smoking, and functional limitation. Rehospitalized patients received similar intensities of SN, HA, and OT as, and less intensive PT than, non-rehospitalized patients (all $P < .05$; see Table 1).

Association Between HHC and 30-Day Rehospitalization

The multivariate Cox proportional model (Table 2) and the Kaplan-Meier survival curves (Figure 2) showed an inverse dose-response relationship between PT and rehospitalization, adjusting for significant covariates. As the PT visit intensity increased, the hazard of rehospitalization decreased by 41% (threshold = 1.36 visits/week) and up to 82% (highest intensity quartile: 2.30 visits/week) in the 60-day HHC episode (both $P < .000$). The Kaplan-Meier survival curves of rehospitalization crossed among different quartiles of SN visit intensity (Figure 3). The hazard ratio (HR) of rehospitalization decreased as SN visit intensity increased, where the highest quartile of SN intensity (threshold = 2.51 visits/week) decreased the hazard of rehospitalization during the 60-day HHC episode by 48% (Table 2). No additive effect was found between PT and SN, as shown in the Kaplan-Meier survival curves (Figure 4) and 95% confidence intervals of adjusted HRs: HR(SN_high) = 0.31 to 0.84; HR(PT_high) = 0.25 to 0.54; and HR(PT_high*SN_high) = 0.09 to 4.86 (model not shown). Visit intensity of HA and OT was not significantly related to rehospitalization in the 60-day HHC episode.

Moderation of Functional Limitation on the Effect of HHC

Subgroup analysis (Table 3) revealed a similar effect of PT and different effects of SN on rehospitalization between the high and low functional limitation groups. Greater PT intensity reduced the hazard of rehospitalization during the 60-day HHC episode in both groups, and the effect was more pronounced in the group with low functional limitation. Greater SN intensity only reduced the hazard of rehospitalization in the low functional limitation group, after adjusting for significant covariates. In both groups, HA and OT visit intensities were not significantly related to rehospitalization.

Discussion

This was the first study that systematically examined the relationships between specific SN, PT, OT, and HA services in HHC and subsequent rehospitalization at varied visit intensity. This study demonstrated 2 principal results. First, there was inverse

Table 1
Sample Characteristics

Variable	Entire Sample (N = 1377)	Rehospitalization		
		No (n = 1219; 11.47%)	Yes (n = 158; 88.53%)	*P* Value*
Age, mean (SD)	79.0 (8.40)	78.9 (8.29)	79.6 (9.15)	
Female	52 (717)	52 (637)	51 (80)	
Race/ethnicity				
Caucasian	82 (1127)	82 (1004)	78 (123)	
African American	14 (197)	14 (167)	19 (30)	
Other	4 (53)	4 (48)	3 (5)	
Married	48 (656)	48 (588)	43 (68)	
Living alone	27 (379)	28 (341)	24 (38)	
Medicare and Medicare dual eligibility	6 (77)	5 (66)	7 (11)	
Number of days during index hospitalization, mean (SD)	5.4 (6.21)	5.1 (5.66)	7.8 (9.1)	<.000
Number of documented medical diagnoses, mean (SD)	5.7 (0.92)	5.7 (0.97)	5.9 (0.34)	<.01
Having the maximum number of 6 diagnoses	88 (1212)	88 (1067)	96 (151)	<.01
Hypertension	72 (997)	72 (879)	75 (118)	
Heart failure	22 (309)	21 (250)	37 (59)	<.000
Diabetes	32 (446)	32 (386)	38 (60)	
Osteoarthritis	24 (332)	25 (307)	26 (25)	<.000
COPD	11 (149)	10 (124)	16 (25)	<.05
Number of medications, mean (SD)	13 (5.58)	12 (5.38)	15 (6.59)	<.000
Taking ≥10 medications	60 (832)	58 (713)	75 (119)	<.000
Cognitive impairment				
No	23 (311)	23 (284)	17 (27)	
Mild	59 (809)	62 (755)	62 (98)	
Moderate/severe	19 (257)	15 (180)	21 (33)	
Daily interfering pain	71 (975)	71 (862)	72 (113)	
Depressive symptoms	22 (305)	21 (260)	28 (45)	
Smoking	18 (245)	17 (208)	23 (37)	<.05
Obesity	18 (246)	17 (213)	21 (33)	
Exhaustion	47 (650)	46 (556)	59 (94)	<.001
Receiving daily assistance from informal caregiver(s)	87 (1196)	87 (1056)	89 (140)	
Composite score of functional limitation, mean (SD)	6.4 (1.06)	6.3 (1.07)	6.7 (0.96)	<.000
Functional limitation group				
Low functional limitation	51 (697)	52 (635)	39 (62)	
High functional limitation	49 (680)	48 (584)	61 (96)	<.01
No. of days between index hospital discharge and HHC admission, mean (SD)	1.4 (1.78)	1.4 (1.15)	1.2 (4.20)	
No. of HHC days, median (Q_1, Q_3)	25 (15, 40)	25 (15, 39)	20 (10, 43)	
No. of SN visits/week, median (Q_1, Q_3)	1.5 (0.9, 2.0)	1.5 (0.9, 2)	1.4 (0.9, 19)	
No. of PT visits/week, median (Q_1, Q_3)	0.9 (0, 1.8)	1 (0, 1.9)	0.6 (0, 1.2)	<.000
No. of OT visits/week, median (Q_1, Q_3)	0 (0, 0)	0 (0, 0)	0 (0, 0)	
No. of HA visits/week, median (Q_1, Q_3)	0 (0, 0)	0 (0, 0)	0 (0, 0)	

Values are % (n) unless otherwise noted.
*t test or U test for continuous variables; χ^2 for categorical variables.

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Table 2
Association of HHC Services With Rehospitalization in Multivariate Cox Proportional Hazard Model

Variables	HR (95% CI)	*P* Value
Age	1.01 (0.99, 1.03)	.49
Female (reference: male)	0.93 (0.66, 1.30)	.66
Married (yes/no)	0.99 (0.68, 1.44)	.94
Living alone (yes/no)	0.80 (0.53, 1.22)	.30
Race (reference: Caucasian)		
African American	0.84 (0.54, 1.31)	.44
Other	0.86 (0.30, 2.42)	.77
Medicaid (yes/no)	0.92 (0.47, 1.79)	.81
Number of days during index hospitalization	1.04 (1.02, 1.05)	<.001
Number of medical conditions	1.30 (0.82, 2.07)	.27
Diagnosis of heart failure (yes/no)	1.28 (0.90, 1.81)	.17
Taking ≥10 medications (yes/no)	1.70 (1.15, 2.52)	.008
Cognitive functioning (reference: no impairment)		
Mild impairment	1.00 (0.63, 1.59)	.99
Moderate to severe impairment	1.09 (0.62, 1.93)	.76
Depressive symptoms (yes/no)	0.98 (0.68, 1.41)	.92
Smoking (yes/no)	1.29 (0.87, 1.91)	.21
Exhaustion (yes/no)	1.32 (0.94, 1.86)	.11
Functional limitation (composite score)	1.15 (0.93, 1.41)	.20
SN weekly visit intensity [reference: quartile 1 (0-0.93, mean 0.52, median 0.30)]		
Quartile 2 (0.94-1.46, mean 1.21, median 1.21)	0.99 (0.64, 1.53)	.96
Quartile 3 (1.47-1.98, mean 1.71, median 1.70)	0.68 (0.42, 1.09)	.11
Quartile 4 (1.99-14, mean 3.36, median 2.51)	0.52 (0.31, 0.87)	.013
PT weekly visit intensity [reference: quartile 1 (0-0, mean 0, median 0)]		
Quartile 2 (0.12-0.90, mean 0.52, median 0.54)	0.94 (0.62, 1.43)	.76
Quartile 3 (0.91-1.75, mean 1.36, median 1.36)	0.59 (0.37, 1.95)	.029
Quartile 4 (1.76-7, mean 2.53, median 2.30)	0.18 (0.09, 1.36)	<.001
OT weekly visit intensity [reference: quartile 1 (0-0, mean 0, median 0)]		
Quartile 2 (0-0, mean 0, median 0)	—	—
Quartile 3 (0-0, mean 0, median 0)	—	—
Quartile 4 (0.12-3.38, mean 0.67, median 0.47)	0.73 (0.50, 1.09)	.12
HA weekly visit intensity [reference: quartile 1 (0-0, mean 0, median 0)]		
Quartile 2 (0-0, mean 0, median 0)	—	—
Quartile 3 (0-0, mean 0, median 0)	—	—
Quartile 4 (0.12-5.25, mean 0.98, median 0.47)	1.46 (0.91, 2.35)	.12

dose-response relationship between HHC (PT, SN) visit intensity and hazard of rehospitalization. Second, intensive PT had a more pronounced effect on reducing the hazard of rehospitalization in the group with lower, rather than higher, functional limitation, and SN reduced the hazard of rehospitalization in only the lower functional limitation group. PT and SN did not have significant additive effects on rehospitalization.

This study concurs with previous research that HHC is effective in avoiding rehospitalization[13] for which a threshold dose exists.[10] This study extended prior research that mostly assessed the aggregated dose of HHC[13,19,26] by examining the respective effect of each HHC service on rehospitalization. Using this approach, we found that HA and OT were not significantly related to rehospitalization, and both PT and SN effectively lowered the risk of rehospitalization in dose-response relationships. The threshold was 1 PT visit/week or 2 SN visits/week. The highest quartile of PT and SN visit intensity (3 visits/week) was related to the lowest hazard of rehospitalization.

The differential effects on rehospitalization among HHC services may be related to different foci of these services. For example, HA is not intended to facilitate functional recovery but to compensate existing functional limitations. Therefore, greater HA visit intensity is likely an indicator of greater functional limitation[15] and higher, instead of lower, hazard of rehospitalization. Similarly, OT is focused on refined muscular performance (eg, swallowing or speaking), when it is grand motor movement of lower extremity (eg, gait speed, falls; focus of PT) that is significantly related to rehospitalization.[19] It is also possible that the null effects of HA and OT were related to their low percentages of use (23% and 8%).

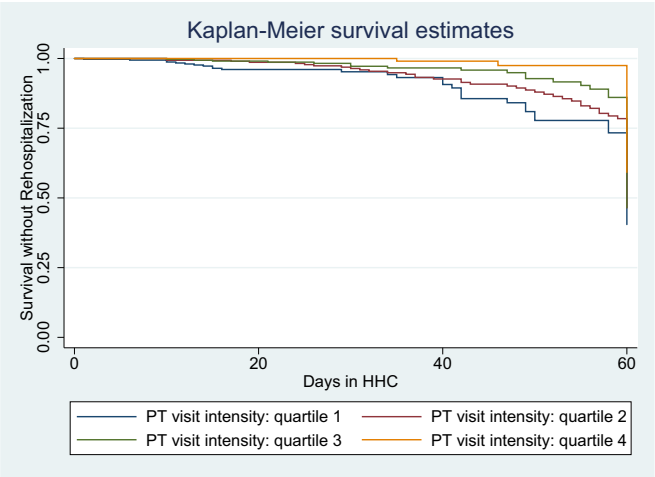

Fig. 2. Kaplan-Meier survival curves of rehospitalization per PT visit intensity.

The effect of SN on rehospitalization differed as patients' level of functional limitation changed, as greater SN visit intensity only decreased the hazard of rehospitalization among patients with low functional limitation. One possible explanation is that the high functional limitation group are usually "sicker," with more complex medical conditions, and thus are less able to enact on SN services that focus on self-management of chronic disease and medication. Another explanation is that compared with patients with lower functional limitation, patients with a higher functional limitation may have a higher threshold of SN, possibly so high that it exceeded the range of SN intensity captured in this study. The last is the unknown role of caregiving in SN effect on rehospitalization. When visiting chronically ill patients,[9] HHC nurses engage the caregivers on disease management and medication education to retain SN effects between visits.[27] Given that chronic conditions are common in HHC patients (eg, heart

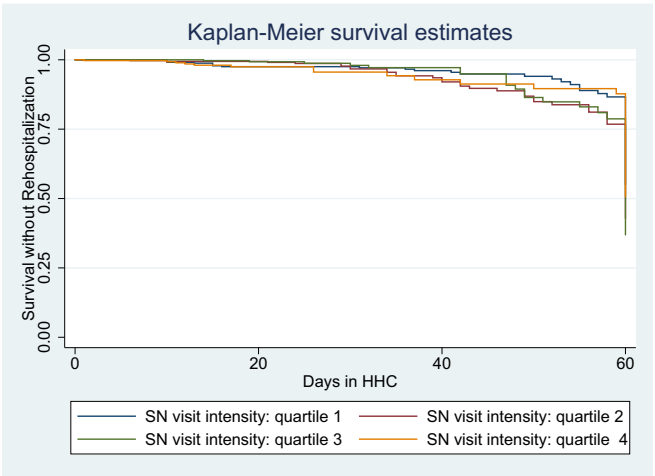

Fig. 3. Kaplan-Meier survival curves of rehospitalization per SN visit intensity.

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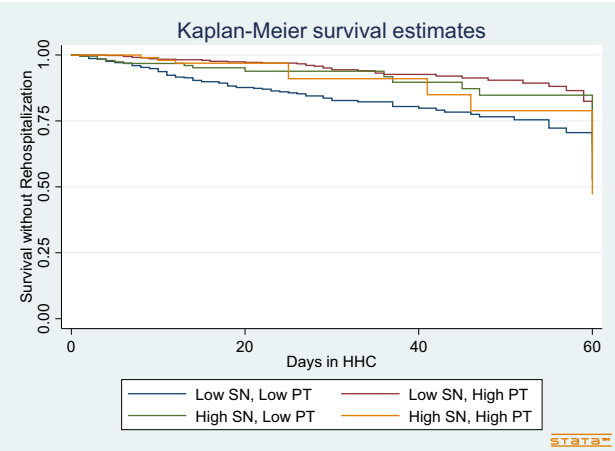

Fig. 4. Kaplan-Meier survival curves of rehospitalization: interaction between PT and SN visit intensity.

failure 22%, diabetes 22%) and 89% required daily caregiving assistance, further research is needed to examine how caregiver assistance affects the effect of SN on rehospitalization.

Older hospitalized patients are usually discharged with worse functional status than their prehospitalization baseline,[28] highlighting the need of functional improving services (PT). In this study, PT decreased the hazard of rehospitalization to a greater extent in patients with lower versus higher functional limitation (HR: 0.09 vs 0.24). This may be because patients with higher functional limitation have more severe and complex medical conditions[19,29] and are more likely to be rehospitalized despite receiving an equal amount of PT as others. However, even in the low functional limitation group, the mean composite score of functional limitation was not necessarily low (5 of 9). This is not surprising, as older hospitalized patients are often referred to HHC because of functional limitation. Yet the relatively high level of functional limitation also suggests medical complexity and a need for intensive, integrated care management. It is thus alarming that the average visits/week of SN (1.5) and PT (0.9; Table 1) were both lower than the threshold (2.51, 1.36; Table 2). This suggests that patients did not receive enough HHC after hospital discharge.

This finding highlights the complex medical and functional conditions in HHC patients, thus the need of "precision HHC." Currently, the dose of HHC is primarily determined based on personal experience and agency protocols.[30] In light of recent Medicare value-based purchasing model that penalizes HHC agencies with above-average rehospitalization rates,[31] a systematic approach should be developed to individualize HHC intensity and ensure that enough HHC services be provided for persons at risk for rehospitalization.

Study Limitations

Study sample was from 1 HHC agency and patients with severe mental, neurologic, and malignant diseases were excluded, which limits the generalizability of the findings. Nevertheless, the sample had comparable demographic, clinical, and functional characteristics to the national older HHC population,[29,32] except for a lower percentage of females (52% vs 62.5%) and a higher rate of heart failure (22% vs 16%). Additionally, we calculated SN intensity without adjusting for frontloading, that is, providing 60% of SN visits in the first 2 weeks of HHC.[33] Though frontloading allows nurses more time for

Table 3
Subgroup Analysis of Patients With Low versus High Functional Limitation at HHC Admission in Multivariate Cox Proportional Model

Subgroup	Group 1: Low Functional Limitation		Group 2: High Functional Limitation	
Variables	HR (95% CI)	*P* Value	HR (95% CI)	*P* Value
Age	1.02 (0.99, 1.06)	.214	1.00 (0.97, 1.03)	.945
Female (reference: male)	0.83 (0.47, 1.48)	.528	1.05 (0.67, 1.64)	.842
Married (yes/no)	1.03 (0.54, 1.95)	.928	0.96 (0.59, 1.57)	.881
Living alone (yes/no)	0.89 (0.47, 1.68)	.723	0.74 (0.41, 1.32)	.306
Race (reference: Caucasian)				
African American	0.68 (0.29, 1.62)	.390	0.85 (0.49, 1.47)	.551
Other	1.42 (0.38, 5.29)	.603	0.38 (0.05, 2.84)	.344
Medicare and Medicaid dual eligibility (yes/no)	1.41 (0.45, 4.39)	.558	0.80 (0.33, 1.93)	.618
Number of days during index hospitalization	1.05 (1.01, 1.09)	.021	1.03 (1.00, 1.05)	.023
Number of medical conditions	1.84 (0.73, 4.62)	.193	1.09 (0.62, 1.91)	.763
Diagnosis of heart failure (yes/no)	1.70 (0.95, 3.03)	.073	1.16 (0.73, 1.84)	.531
Taking ≥10 medications (yes/no)	1.25 (0.69, 2.24)	.460	2.12 (1.20, 3.76)	.01
Cognitive function (reference: no impairment)				
Mild impairment	1.15 (0.62, 2.15)	.656	0.83 (0.40, 1.69)	.602
Moderate to severe impairment	0.72 (0.20, 2.55)	.605	0.99 (0.45, 2.19)	.987
Depressive symptoms (yes/no)	0.78 (0.41, 1.50)	.463	1.18 (0.73, 1.89)	.504
Smoking (yes/no)	1.17 (0.63, 2.21)	.617	1.33 (0.78, 2.27)	.298
Exhaustion (yes/no)	1.18 (0.69, 2.01)	.545	1.37 (0.83, 2.27)	.218
Functional limitation (composite score)	1.25 (0.83, 1.87)	.280	1.50 (0.89, 2.52)	.129
SN weekly visit intensity [reference: quartile 1 (0-0.93, mean 0.52, median 0.30)]				
Quartile 2 (0.94-1.46, mean 1.21, median 1.21)	1.09 (0.54, 2.20)	.818	0.89 (0.50, 1.61)	.709
Quartile 3 (1.47-1.98, mean 1.71, median 1.70)	0.41 (0.18, 0.93)	.034	0.84 (0.47, 1.52)	.568
Quartile 4 (1.99-14, mean 3.36, median 2.51)	0.29 (0.12, 0.75)	.011	0.63 (0.33, 1.21)	.165
PT weekly visit intensity [reference: quartile 1 (0-0, mean 0, median 0)]				
Quartile 2 (0.12-0.90, mean 0.52, median 0.54)	0.70 (0.35, 1.38)	.302	1.09 (0.61, 1.96)	.763
Quartile 3 (0.91-1.75, mean 1.36, median 1.36)	0.61 (0.30, 1.24)	.174	0.59 (0.31, 1.15)	.119
Quartile 4 (1.76-7, mean 2.53, median 2.30)	0.08 (0.02, 0.31)	<.001	0.25 (0.10, 0.58)	<.001
OT weekly visit intensity [reference: quartile 1 (0-0, mean 0, median 0)]				
Quartile 2 and 3: both (0, 0, mean 0, median 0)	—	—	—	—
Quartile 4 (0.12-3.38, mean 0.67, median 0.47)	0.60 (0.25, 1.39)	.230	0.81 (0.51, 1.27)	.356
HA weekly visit intensity [reference: quartile 1 (0, 0, mean 0, median 0)]				
Quartile 2 and 3: both (0, 0, mean 0, median 0)	—	—	—	—
Quartile 4 (0.12-5.25, mean 0.98, median 0.47)	1.53 (0.57, 4.14)	.402	1.40 (0.78, 2.50)	.258

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assessment and developing plans of care at the beginning of HHC,[9,32] it may limit SN intensity in the later phase of HHC because Medicare reimbursement/episode for SN is fixed. Not having real-time information about SN intensity may skew the results of patients whose HHC stay was not close to average.

Conclusions/Relevance

At the threshold of 1 PT visit or 2 SN visits/week, HHC decreased the hazard of rehospitalization among older HHC patients by up to 82% and 48%, respectively. Differential impact of HHC across disciplines calls for "precision HHC"—using targeted interdisciplinary services to address specific medical, functional, and behavioral risk factors of rehospitalization. Older patients should receive enough HHC to improve clinical and functional status sufficiently to reduce the risk of rehospitalization. Future research should use national data (OASIS, Medicare claims) and examine the mechanism of each HHC service on rehospitalization.

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Supplementary Data

Supplementary data related to this article can be found online at https://doi.org/10.1016/j.jamda.2018.10.021.

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