HSR Health Services Research

DOI: 10.1111/1475-6773.12667
RESEARCH ARTICLE

Home Health Care: Nurse–Physician Communication, Patient Severity, and Hospital Readmission

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Objective. To evaluate whether communication failures between home health care nurses and physicians during an episode of home care after hospital discharge are associated with hospital readmission, stratified by patients at high and low risk of readmission.

Data Source/Study Setting. We linked Visiting Nurse Services of New York electronic medical records for patients with congestive heart failure in 2008 and 2009 to hospitalization claims data for Medicare fee-for-service beneficiaries.

Study Design. Linear regression models and a propensity score matching approach were used to assess the relationship between communication failure and 30-day readmission, separately for patients with high-risk and low-risk readmission probabilities.

Data Collection/Extraction Methods. Natural language processing was applied to free-text data in electronic medical records to identify failures in communication between home health nurses and physicians.

Principal Findings. Communication failure was associated with a statistically significant 9.7 percentage point increase in the probability of a patient readmission (32.6 percent of the mean) among high-risk patients.

Conclusions. Poor communication between home health nurses and physicians is associated with an increased risk of hospital readmission among high-risk patients. Efforts to reduce readmissions among this population should consider focusing attention on this factor.

Key Words. Visiting nurse services, home health care, readmissions, health care delivery

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Home health care (HHC) occupies a large role in the American health care delivery system. Use of the HHC benefit under Medicare has grown rapidly in terms of volume of users, from 2.5 million in 2002 to 3.5 million in 2013, as well as in terms of the proportion of Medicare beneficiaries using the benefit, from 7.2 percent in 2002 to 9.3 percent in 2013 (MEDPAC 2015). HHC provides skilled nursing or therapy to homebound Medicare beneficiaries. Reducing potentially avoidable hospitalizations is an important quality objective of home health agencies, and the rate of hospitalizations among Medicare beneficiaries served by agencies is publicly reported by CMS (Centers for Medicare & Medicaid Services 2015). In 2009, the average Medicare charges on a per day basis for hospital care came to $6,200 per day, skilled nursing facility care was $622 per day, and HHC was $135 per day (Polsky, David, and Yang 2014). The potential cost savings of HHC through substitution for subacute care and the likely increase in demand that HHC will experience as the U.S. population ages have elevated the role of HHC in the U.S. health care delivery system. The creation of Accountable Care Organizations and the implementation of the Hospital Readmission Reduction Program—a program that transfers Medicare payments from hospitals that perform poorly in preventing readmissions to hospitals that perform well—by the ACA may also incentivize the use of HHC when it could reduce overall costs and prevent readmissions.

The full HHC benefit under Medicare provides beneficiaries with in-home skilled nursing care by a registered nurse or licensed practical nurse and supporting services from home health aides, therapists (i.e., physical, speech, and occupational therapists), medical social services, and medical supplies (Polsky, David, and Yang 2014). Medicare beneficiaries may receive HHC free of charge if they require part-time (fewer than 8 hours per day) or intermittent (temporary but not indefinite) skilled care and are unable to leave their homes without considerable effort (MEDPAC 2013). Each episode of HHC is for up to 60 days and can be renewed if needed (MEDPAC 2013). Medicare adjusts its payment to HHC providers based on several factors, including measures of patients' clinical and functional severity and the use of therapy during the home health episode (Polsky, David, and Yang 2014). Skilled nursing accounted for 53 percent of total visits delivered to beneficiaries under the HHC benefit in 2013, and therapists accounted for 36 percent of total visits (MEDPAC 2015).

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Under Medicare HHC, all episodes must be referred by a physician, and the delivery of care by the HHC must be coordinated with a physician. HHC agencies are required to provide documentation of a face-to-face encounter between the patient and a certifying physician that includes attestation that HHC services are provided while the patient is under the care of a physician. The physician referral to HHC, however, does not require a preceding hospital or inpatient stay as it does under the Medicare Skilled Nursing Facility (SNF) benefit. Much of the recent growth of Medicare HHC has been among patients admitted from the community. In 2012, community admissions represented 66 percent of all Medicare HHC episodes, with the remaining 34 percent of episodes preceded by a hospitalization or postacute stay (MEDPAC 2015).

Effective communication between the HHC nurses and the physician is needed to, among other things, approve the overall HHC plan of care, treat new symptoms, facilitate care coordination, identify possible medication interactions, and respond to changes in clinical status. We use readmissions as an outcome variable in this study because avoiding unplanned readmissions is a primary goal of HHC for patients who enter the program directly from the hospital (Polsky, David, and Yang 2014).

In this study, we examine Medicare patients who received HHC from the Visiting Nurse Service of New York (VNSNY) in 2008 or 2009 to determine how a patient's probability of a readmission is affected by communication failures between the HHC nurses and physicians.

For background, VNSNY is the largest HHC provider in the New York City area. It is nonprofit and is not integrated with any specific hospital. It provides comprehensive HHC services of nursing care, physical care, occupational therapy, speech therapy, medical social services, and home health aides. In 2014, it was one of 49 HHC providers serving the New York City area (Centers for Medicare & Medicaid Services 2015).

Given the recent policy and demographic changes that have elevated the role of HHC in the U.S. health care delivery system, improving the operation of this service is of crucial importance for lowering health care costs and improving the quality of health care delivery. In this study, we investigate one aspect of quality in this program: communication between HHC nurses and physicians. We previously identified a small, statistically insignificant positive association between communication failure and readmission (Press et al. 2015). In this study, we expand Press et al. (2015) by separately analyzing the probability of a readmission for high-risk and low-risk patients using stratified and interaction models. We also explore how results are influenced by propensity score matching.

Data

Our two primary data sources are the Medicare Provider Analysis and Review (MedPAR) file and VNSNY electronic medical records (EMRs). The VNSNY EMR contains information on HHC episode start dates for each patient and information on each nurse communication to physicians throughout the HHC episode. We first identified Medicare fee-for-service beneficiaries in 2008 and 2009 who received home health care from VNSNY and had a home health diagnosis of congestive heart failure according to VNSNY EMR data. This CHF diagnosis was the primary diagnosis in 47.1 percent of cases. We matched these patients to the hospitalization information contained in MedPAR for fee-for-service beneficiaries. Index hospital discharges were identified for cases in which there was an HHC start date within 8 days of discharge. For this base sample, we identified the presence of an all-condition readmission between the start of home care and 30 days after the index hospital discharge. We identified readmissions in accordance with the specifications of the all-condition readmission measure developed by the Centers for Medicare and Medicaid Services (CMS) and Yale University (Yale New Haven Health Services Corporation/Center for Outcomes Research & Evaluation 2014), which excludes "planned" readmissions. We used 30-day readmission rates because this is the focus of several recent incentive programs, such as the Hospital Readmission Reduction Program.

We focus on patients with CHF to assist in standardizing our population. Additionally, CHF is often a chronic condition for which exacerbations can be potentially managed with timely, well-coordinated care provided in outpatient settings, assisted by HHC. Therefore, readmissions of these patients may be particularly sensitive to communication failures between HHC nurses and physician. CHF also was among the first conditions introduced in the CMS Hospital Readmission Reduction Program.

For each episode of HHC, we assigned a category indicating failure or success for each attempted nurse communication based on free-text data in the VNSNY EMR. This assigned categorization was performed using a natural language processing (NLP) algorithm. As explained in Press et al. (2015), the NLP algorithm parsed the nurses' free-text comments in the EMR for the key phrases specific to each category of communication. Across the set of key phrases, concept lists represented by phrase components were created (e.g., MD, PMD, DR, DOCTOR, and PHYSICIAN for the MD concept). Then, the free-text comments were processed to identify matches between phrase components and the master concepts. The assigned categories of communication were validated by manual review of select records (Press et al. 2015). EMRs provide big data that can be rapidly analyzed using NLP. One recent study applied NLP to quantify care coordination activities used by nurse care coordinators and HHC nurses (Popejoy et al. 2015).

Our NLP algorithm used the following communication categories. The communication category “A” represents a conversation between the nurse and physician and may include indirect conversations in which the physician was actively communicating with the visiting nurse through an intermediary. Category “B” represents a conversation between the nurse and the physician’s office staff, but not involving the physician. Category “C” represents a one-way communication in which the nurse left a message, paged the physician, or sent a fax. A small number of free-text communications contained evidence that communication was established, but the communication could not be placed into an exact category and so these are considered category “ABC” communications. Category “D” represents a communication failure in which the nurse was unable to reach the physician, physician office staff, or to leave a message. Category D communications are considered communication failures compared to the other categories. From the analysis of free-text responses, we found no mention of e-mail communication. Some communications were listed as strictly containing administrative information about start of home health care, and we discarded these as they did not provide any meaningful information on the communication.

We utilize several data sources to obtain control variables for patients, physicians, and nurses. Patient characteristics include 20 patient comorbidities (chronic conditions from the year prior), age, gender, race, and dual eligibility for Medicare and Medicaid. The Beneficiary Annual Summary File (BASF) provides these data. Additionally, the VNSNY EMR provides additional patient characteristics indicating patient clinical and functional health, cognitive function, English language, county of residence, and caregiver support at home. VNSNY also provides information on nurse characteristics, including the gender, payment structure, years of experience, and highest degree completed, and the specialty type of the physician responsible for coordinating the episode of HHC. The American Medical Association Masterfile provides additional information on board certification, US training, age, and gender for the coordinating physician. The US Census Bureau provides ZIP code–level median household income.

For our primary analysis, we use 2,680 episodes of HHC in which there was only one attempt by the HHC nurse to communicate with the physician.

Within 30 days of discharge or until a readmission (whichever occurred earlier), approximately 41.0 percent of the episodes of VNS care had one communication attempt, 28.2 percent had two communication attempts, 13.8 percent had three communication attempts, and 17.0 percent had between 4 and 25 communication attempts (median = 5). These one-communication HHC episodes were provided by 778 unique nurses, and the patients were discharged from 82 unique institutions. As a sensitivity analysis, we also explore the robustness of our results to using an average communication failure rate variable for all 6,538 cases.

Table 1 provides patient, nurse, and physician descriptive statistics for episodes of HHC for our two samples of one-communication patients and all patients. The readmission rate for patients with episodes of HHC with only one attempt is higher than the average across the full sample, 22 percent compared to 18 percent.

EMPIRICAL METHODS

In this article, we test the hypothesis that a failed communication attempt between the HHC nurse and physician affects a patient's probability of being readmitted. We calculate communication failure in two ways, by performing our analysis using 2,680 episodes of HHC in which there was exactly one communication attempt, and then again for all 6,538 episodes of HHC and using the mean communication failure rate as the treatment variable.

In the most basic specification, we estimate the association between a communication failure (category D) and patient 's probability of being readmitted:

$$\text{readmission}_{\text{npi}} = \alpha + \beta_1 \, \text{communication\_D}_{\text{npi}} + \varepsilon_{\text{npi}} \qquad (1)$$

where $\text{communication\_D}_{\text{npi}}$ equals either 1 if category D communication occurred between VNS nurse n with physician p about patient i (and 0 if not) in one communication cases, or is the mean communication failure rate for all documented communications. We hypothesize that β_1 will be positive, suggesting that communication failures increase the probability of a patient readmission.

We reestimate (1) by adding patient characteristics, including indicators for the patient's borough of residence. Following, we iteratively add HHC nurse characteristics, physician characteristics (for the physician responsible for coordinating the episode of HHC), and then hospital indicators. We

Table 1: Descriptive Statistics

	One Communication Only		*All Communications*	
	Mean	*SD*	*Mean*	*SD*
Beneficiary characteristics				
Readmission within 30 days	0.22	0.42	0.18	0.38
Age	80.46	10.74	80.54	10.72
White	0.54	–	0.57	
Black	0.23	–	0.19	
Hispanic	0.19	–	0.19	
Other or unknown race/ethnicity	0.05	–	0.05	
Female	0.64	–	0.62	
<$30,000 household income in ZIP of residence	0.30	–	0.28	
$30,000–$50,000 household income in ZIP of residence	0.41	–	0.39	
>$50,000 household income in ZIP of residence	0.28	–	0.31	
Missing household income in ZIP of residence	0.01	–	0.02	
Dual eligible	0.36	–	0.35	
Number of comorbidities	5.93	1.84	5.86	1.80
Understands English	0.68	–	0.67	
Support role person lives outside home	0.52	–	0.54	
Support role person resides in home (excluding paid help)	0.46	–	0.44	
Support role person is paid help	0.17	–	0.19	
Cognitive impairment	0.03	–	0.03	
Nonfunctional score (0–12)	7.54	2.59	7.41	2.66
Brooklyn residence	0.28	–	0.24	
Bronx residence	0.14	–	0.12	
Queens residence	0.22	–	0.21	
Manhattan residence	0.22	–	0.28	
Nassau residence	0.06	–	0.06	
Staten Island residence	0.05	–	0.05	
Westchester residence	0.02	–	0.03	
Nurse characteristics				
Years experience	7.11	6.89	7.08	7.22
Male	0.17	–	0.16	
Full-time	0.66	–	0.68	
Part-time	0.01	–	0.02	
Per diem	0.32	–	0.31	
Less than bachelor's degree	0.34	–	0.33	
Bachelor's degree	0.54	–	0.55	
More than bachelor's degree	0.10	–	0.10	
Missing education	0.02	–	0.02	
Physician characteristics				
Primary care	0.59	–	0.51	
Nonsurgeon subspecialist	0.35	–	0.41	

Continued

Table 1. *Continued*

	One Communication Only		*All Communications*	
	Mean	*SD*	*Mean*	*SD*
Surgeon	0.06	–	0.07	
Missing physician specialty	0.00	–	0.00	
US residency training	0.49	–	0.43	
Non-US residency training	0.46	–	0.52	
Missing residency training information	0.06	–	0.05	
Board certified	0.10	–	0.09	
Non– board certified	0.84	–	0.86	
Missing certification information	0.06	–	0.06	
≤40 years old	0.23	–	0.23	
41–50 years old	0.29	–	0.29	
51–60 years old	0.28	–	0.28	
>60 years old	0.14	–	0.15	
Missing age	0.06	–	0.05	
Male	0.74	–	0.75	
Female	0.20	–	0.19	
Missing gender	0.06	–	0.05	
Sample size	2,680		6,538	

Notes. The number of total comorbidities is provided here, but in the analysis, we include separate indicator variables for each of the 20 comorbidities. Numbers may not sum to 100% due to rounding.

iteratively include these controls to observe whether any particular set of controls changes the estimate of a communication failure on a patient readmission. Our full specification is here:

$$\text{readmission}_{\text{npih}} = \alpha + \beta_1 X_i + \beta_2 \text{nurse\_char}_n + \beta_3 \text{phy\_char}_p + \beta_4 \theta_h + \beta_5 \text{communication\_D}_{\text{npih}} + \varepsilon_{\text{npih}} \quad (2)$$

where $\text{communication\_D}_{\text{npih}}$ is equal to 1 if the sole nurse communication occurring between VNS nurse n with physician p about patient i, who was discharged from hospital h, was a failure. $\text{Readmission}_{\text{npih}}$ continues to equal 1 if there was a readmission within 30 days of discharge. X_i is a set of controls at the patient level: age, age squared, gender, race (white, black, Hispanic, other/unknown), indicators for 20 Chronic Condition Warehouse comorbidities, ZIP code–level household median income (<30k, 30–50k, >50k, missing), dual eligibility for Medicaid and Medicare, understands English, cognitive impairment, functional status, and presence of informal support. Nurse_char_n is a set of controls at the nurse level: years of experience, gender, contract structure (full-time, part-time, per diem), and education (less than a bachelor's degree, bachelor's degree only, more than a bachelor's degree, missing). Phy_char_p is a set of controls at the level of the physician responsible for the episode of HHC: US training (no, yes, missing), board certification (no, yes, missing), age (≤40 years, 41–50, 51–60, >60, missing), and gender. θ_h is a vector of indicator variables for each hospital that discharged patients, allowing us to exploit variation in readmission rates within each discharging hospital.

It is possible that category B (nurse-to-staff) and category C (one-way) communications may also be differentially associated with a patient's probability of a readmission than a category A communication (nurse-to-physician). Therefore, we add category B and C communications as independent variables to the full model in (2) for one-communication patients. Using our one-communication sample, we can now demonstrate the association that category B, C, and D communications have on readmission rates, compared to category A communication.

$$\begin{aligned}\text{readmission}_{npih} = {} & \alpha + \beta_1 X_\text{i} + \beta_2 \text{nurse\_char}_\text{n} + \beta_3 \text{phy\_char}_\text{p} + \beta_4 \theta_\text{h} \\ & + \beta_5 \text{communication\_B}_\text{npih} + \beta_6 \text{communication\_C}_\text{npih} \\ & + \beta_7 \text{communication\_D}_\text{npih} + \varepsilon_\text{npih}\end{aligned}$$

We hypothesize that any communication should be better than a failed communication attempt, so β_7 may be larger than β_5 and β_6. To obtain conservative estimates, we treat a small number of communications in which we could not determine whether the communication was category A, B, or C (mentioned earlier) as a category A communication. This treatment is conservative in the sense that it will bias estimates of communication failure toward the null of no effect.

We also estimate stratified and interaction models to explore whether communication failure disproportionately influences patients at the lowest and highest risk of having a 30-day readmission. We identify low- and high-risk patients by regressing readmission occurrence against clinically relevant patient-level characteristics of gender, age, race, cognitive impairment, functional status, and all comorbidities. We use these regression estimates to calculate predicted probabilities of a patient readmission and stratify our analysis by predicted probabilities of a readmission being above or below the median. We also estimate an interaction model by interacting communication categories with having an above-the-median readmission risk.

We use a linear probability model for the primary analyses. Standard errors are clustered at the HHC nurse and hospital level. These two levels are non-nested (e.g., HHC nurses see patients spanning hospitals), so we use a two-way cluster option described by Cameron (2011). As a sensitivity analysis, we compare the association that a communication failure has on readmission among similar individuals, by using propensity scores. We use our one-communication sample for this propensity score analysis, because the negative treatment of communication failure is an indicator variable. We use Stata version 14.1's -teffects psmatch- command for the propensity score-matching approach.

RESULTS

Table 2 provides preliminary results of the association of communication failure on a patient's probability of a 30-day readmission. Communication failures were the least common type of communication (11.2 percent) across all episodes of HHC with only one communication. In column 1, we show that a communication failure was associated with a 4.8 percentage point (21.4 percent of the mean) increase in the probability of a patient readmission, and this association was significant at a 10 percent level. The point estimate increases to 5.5 percentage points when controlling for patient characteristics (column

Table 2: Communication Category and Readmission Rates, One Communication Attempt

	%	(1)	(2)	(3)	(4)	(5)	(6)
(1) Category D communication	11.2	0.048* (0.028)	0.055** (0.028)	0.058** (0.028)	0.055** (0.028)	0.056* (0.031)	0.062* (0.033)
(2) Category C communication	25.4						0.030 (0.024)
(3) Category B communication	22.4						−0.013 (0.026)
N		2,680	2,680	2,680	2,680	2,680	2,680
Patient characteristics		No	Yes	Yes	Yes	Yes	Yes
Nurse characteristics		No	No	Yes	Yes	Yes	Yes
Physician characteristics		No	No	No	Yes	Yes	Yes
Hospital indicators		No	No	No	No	Yes	Yes

Notes. The 30-day readmission rate for this sample is 22.4%. "D": nurse unable to reach the physician, physician office staff, or to leave a message (communication failure). "C": nurse left a message, paged the physician, or sent a fax. "B": nurse communicated with the physician's office staff, but not with the physician. "A": nurse communicated directly or indirectly with the patient's physician.
**Significant at the 5 percent level. *Significant at the 10 percent level.

2), and this association is now significant at a 5 percent level. This coefficient largely remains the same when controlling for nurse characteristics, physician characteristics, and hospital (columns 3, 4, and 5). Finally, we jointly assess the association of a category D, C, and B communication compared to a category A communication, controlling for patient, nurse, and physician characteristics, and the hospital (column 6). We find that a communication failure has a 6.2 percentage point (27.7 percent of the mean) increase in the probability of a patient readmission compared to a category A communication, and category C communications have a statistically insignificant 3.0 percentage point (13.4 percent) increase in the probability of a patient readmission. We next identify patients with above and below the median readmission risk. We regress readmission occurrence on clinically relevant patient characteristics of gender, age, race, cognitive impairment, functional status, and all comorbidities separately for one communication patients and for all patients. Our results are shown in Table S1. Eight chronic conditions were associated with statistically significant higher readmission probabilities in both samples: acute myocardial infarction, Alzheimer's disease (and related disorders), atrial fibrillation, chronic kidney disease, chronic obstructive pulmonary disease and bronchiectasis, glaucoma, ischemic heart disease, and depression. We use these regression results to generate predicted readmission probabilities.

In Table 3, we stratify results from Table 2 into individuals with below (panel A) and above (panel B) the median risk of a patient readmission. We find that the two groups had similar incidences of communication failures (10.7 and 11.7 percent). In column (5), we find an insignificant 1.3 percentage point increase in probability of a readmission for low-risk patients with a communication failure, but among the high-risk patients, we observe a statistically significant 9.7 percentage point increase in the probability of a patient readmission (32.6 percent of the mean). Among one-attempt patients, we do not find any evidence of a difference between category A, B, or C communications and readmission (Table 3, column 6). Results from a pooled analysis are presented in panel C and demonstrate the robustness of earlier results. These results show that a communication failure is associated with a 9.6 percentage point greater likelihood of a patient readmission among high-risk patients compared to low-risk patients (42.9 percent of the mean).

Our first sensitivity analysis is to explore how earlier results are affected by propensity score matching based on observable patient, physician, and nurse characteristics. To avoid collinearity while maintaining the same sample used to estimate Tables 2 and 3, we removed endometrial

Table 3: Communication Category and Readmission Rates for High-Risk and Low-Risk Patients, One Communication Attempt

	%	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Low-Readmission-Risk Patients							
(1) Category D communication	10.7	−0.012 (0.033)	0.003 (0.033)	0.009 (0.032)	0.008 (0.032)	0.013 (0.034)	0.004 (0.036)
(2) Category C communication	25.7						0.021 (0.035)
(3) Category B communication	22.5						−0.054 (0.035)
N		1,340	1,340	1,340	1,340	1,340	1,340
Patient characteristics		No	Yes	Yes	Yes	Yes	Yes
Nurse characteristics		No	No	Yes	Yes	Yes	Yes
Physician characteristics		No	No	No	Yes	Yes	Yes
Hospital indicators		No	No	No	No	Yes	Yes
Panel B: High-Readmission-Risk Patients							
(1) Category D communication	11.7	0.096** (0.041)	0.105** (0.044)	0.108** (0.044)	0.105** (0.045)	0.097** (0.048)	0.112** (0.050)
(2) Category C communication	25.1						0.036 (0.033)
(3) Category B communication	22.2						0.011 (0.037)
N		1,340	1,340	1,340	1,340	1,340	1,340
Patient characteristics		No	Yes	Yes	Yes	Yes	Yes
Nurse characteristics		No	No	Yes	Yes	Yes	Yes
Physician characteristics		No	No	No	Yes	Yes	Yes
Hospital indicators		No	No	No	No	Yes	Yes
Panel C: Full Sample							
(1) Category D communication × high readmission risk	11.2	0.107** (0.051)	0.098* (0.051)	0.098* (0.051)	0.097* (0.051)	0.096* (0.054)	0.113** (0.054)
(2) Category C communication × high readmission risk	25.4						0.009 (0.042)
(3) Category B communication × high readmission risk	22.4						0.058 (0.042)
N		2,680	2,680	2,680	2,680	2,680	2,680
Patient characteristics		No	Yes	Yes	Yes	Yes	Yes
Nurse characteristics		No	No	Yes	Yes	Yes	Yes
Physician characteristics		No	No	No	Yes	Yes	Yes
Hospital indicators		No	No	No	No	Yes	Yes

Notes. The 30-day readmission rate for the "low readmission risk" sample is 14.9%, for the "high readmission risk" sample is 29.8%, and for the full sample is 22.4%. "D": nurse unable to reach the physician, physician office staff, or to leave a message (communication failure). "C": nurse left a message, paged the physician, or sent a fax. "B": nurse communicated with the physician's office staff, but not with the physician. "A": nurse communicated directly or indirectly with the patient's physician.

**Significant at the 5 percent level. *Significant at the 10 percent level.

cancer and cognitive impairment as risk factors, merged the two highest ZIP code–level income categories, merged missing physician specialty and primary care, and merged part-time and per diem nurse contract type. After adjusting for underlying observable patient, physician, and nurse characteristics to make as similar as possible the groups receiving and not receiving the negative treatment of a communication failure, we find the patients experiencing a communication failure were associated with a 7.9 percentage point increase in the likelihood of a readmission (p = .014). This suggests that the 5.5 percentage point estimate in Table 2, column 4, which controls for patient, physician, and nurse characteristics, may be a conservative estimate. Among patients with a low readmission risk, we find that they were associated with a 1.6 percentage point increase in the likelihood of a readmission (statistically insignificant); among high-risk patients, they were associated with a 5.0 percentage point increase in the likelihood of a readmission (p = .075). This is the same pattern as observed in Table 3, column 4 in panels A and B. In sum, this propensity score matching analysis supports the same conclusions as the original set of results.

Our second sensitivity analysis is to explore how similar our results are when we use the full sample of 6,538 episodes of HHC. The average communication failure rate per individual was 8.3 percent. We find that the same general pattern holds when we use all episodes of HHC and redefine the treatment variable as the percent communication failure. In column 5 of

Table 4: Communication Category and Readmission Rates, All Communication Attempts

	%	(1)	(2)	(3)	(4)	(5)
(1) D communication mean	8.3	0.064***	0.060**	0.061**	0.060**	0.060**
		(0.024)	(0.024)	(0.024)	(0.024)	(0.026)
N		6,538	6,538	6,538	6,538	6,538
Patient characteristics		No	Yes	Yes	Yes	Yes
Nurse characteristics		No	No	Yes	Yes	Yes
Physician characteristics		No	No	No	Yes	Yes
Hospital indicators		No	No	No	No	Yes

Notes. The 30-day readmission rate for this sample is 17.7%. “D”: nurse unable to reach the physician, physician office staff, or to leave a message (communication failure). “C”: nurse left a message, paged the physician, or sent a fax. “B”: nurse communicated with the physician’s office staff, but not with the physician. “A”: nurse communicated directly or indirectly with the patient’s physician.
***Significant at the 1 percent level. **Significant at the 5 percent level. *Significant at the 10 percent level.

Table 4, we find that the difference between having no communication failures to having only communication failures is a 6.0 percentage point increase in the probability of a readmission (33.9 percent of the mean). In Table 5, panel C, column 5, we observe that the difference between no failures and only failures was associated with a statistically significant 9.1 percentage point greater likelihood of a patient readmission for high-risk patients compared to low-risk patients (51.4 percent of the mean). In sum, this sensitivity analysis suggests that findings from the analysis of patients with one HHC communication apply broadly.

Table 5: Communication Category and Readmission Rates for High-Risk and Low-Risk Patients, All Communication Attempts

	%	(1)	(2)	(3)	(4)	(5)
Panel A: Low-Readmission-Risk Patients						
(1) D communication mean	7.6	0.000	0.009	0.009	0.009	0.010
		(0.026)	(0.025)	(0.025)	(0.026)	(0.027)
N		3,269	3,269	3,269	3,269	3,269
Patient characteristics		No	Yes	Yes	Yes	Yes
Nurse characteristics		No	No	Yes	Yes	Yes
Physician characteristics		No	No	No	Yes	Yes
Hospital indicators		No	No	No	No	Yes
Panel B: High-Readmission-Risk Patients						
(1) D communication mean	9.0	0.102***	0.098***	0.098***	0.096***	0.087***
		(0.032)	(0.033)	(0.033)	(0.033)	(0.036)
N		3,269	3,269	3,269	3,269	3,269
Patient characteristics		No	Yes	Yes	Yes	Yes
Nurse characteristics		No	No	Yes	Yes	Yes
Physician characteristics		No	No	No	Yes	Yes
Hospital indicators		No	No	No	No	Yes
Panel C: Full Sample						
(1) D communication mean ×	8.3	0.101***	0.095**	0.095**	0.094**	0.091**
high readmission risk		(0.039)	(0.038)	(0.038)	(0.038)	(0.040)
N		6,538	6,538	6,538	6,538	6,538
Patient characteristics		No	Yes	Yes	Yes	Yes
Nurse characteristics		No	No	Yes	Yes	Yes
Physician characteristics		No	No	No	Yes	Yes
Hospital indicators		No	No	No	No	Yes

Notes. The 30-day readmission rate for the "low readmission risk" sample is 11.0%, for the "high readmission risk" sample is 24.3%, and for the full sample is 17.7%. "D": nurse unable to reach the physician, physician office staff, or to leave a message (communication failure). "C": nurse left a message, paged the physician, or sent a fax. "B": nurse communicated with the physician's office staff, but not with the physician. "A": nurse communicated directly or indirectly with the patient's physician.

***Significant at the 1 percent level. **Significant at the 5 percent level. *Significant at the 10 percent level.

Conclusion

In this article, we use a novel analysis of data from the HHC EMR matched with Medicare claims data to examine how failures in communication between nurses and physicians during an episode of HHC influence a patient's probability of a 30-day readmission. As the number of nurse communication attempts is endogenously related to the readmission outcome, we explore how communication failure influences readmission given a certain number of communication attempts. Using this approach, we find evidence that communication failure increases the probability of a patient readmission among high-risk patients. However, communication failure is not associated with a higher probability of readmission for low-risk patients.

In a policy environment that offers financial incentives for hospitals, postacute providers, and payers to reduce readmission rates, failures in communication between HHC nurses and physicians may be an important aspect of care to scrutinize for improvement opportunities. As an illustrative example of effect sizes, among patients with exactly one communication, if half of the communication failures from high-risk patients were reallocated to low-risk patients, the readmission rate for all patients would fall 4.8 percentage points (21.4 percent of the mean), all without requiring any reduction in the total number of communication failures. Nurse fixed effects explain 34.7 percent of the variation in communication failures in this study, which suggests that home health agencies could theoretically reduce readmission rates by reallocating to high-risk patients those nurses who are particularly "good communicators." HHC payments remain well in excess of costs (MEDPAC, 2015), which may offer an opportunity for HHC agencies, hospitals, and physicians to focus training and other quality measurement and improvement efforts on improving communication success.

Three limitations of our study may reduce the generalizability of our findings to all episodes of HHC. First, our study is confined to a HHC provider that is not integrated with a hospital. Communication failure may be less common among providers within integrated systems, so our results may not be applicable to those situations. Thirty-one percent of hospital discharges to HHC go to HHC providers that are vertically integrated with the hospital (David, Rawley, and Polsky 2013), and communication quality may be improved in these situations, due to fewer institutional barriers, compared to the majority of cases in which a hospital discharges a patient to a free-standing HHC provider.

Second, our study is performed among a sample of HHC patients with CHF, for which complications may be particularly amenable to management by HHC. This may contribute to larger effect sizes of communication failure compared to other patients. Despite these limitations, we believe that our results have broad implications for the use and improvement of HHC under current policy priorities.

Third, our VNS data does not contain information on when a physician's office unsuccessfully attempts to connect with the HHC nurse. As part of the initial communication that the HHC nurse has with the coordinating physician, the HHC nurse provides the coordinating physician with their contact information. If the physician attempts to contact the HHC nurse and is successful, this communication is recorded in our system (and used in our analysis). If, however, the communication was unsuccessful, then we do not observe this in our study. Many communications are initiated by HHC nurses instead of physicians, and all of these are captured in our data.

Acknowledgments

Joint Acknowledgment/Disclosure Statement: The views expressed in this article are those of the authors and do not necessarily represent the views or policy of the Centers for Medicare & Medicaid Services. The authors have no conflicts of interest to disclose. This research is supported by the Aetna Foundation, a national foundation based in Hartford, Connecticut, that supports projects to promote wellness, health, and access to high-quality health care for everyone. The views presented here are those of the author and not necessarily those of the Aetna Foundation, its directors, officers, or staff. This study was approved by the Weill Cornell institutional review board.

Disclosures: None.

Disclaimer: None.

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Supporting Information

Additional supporting information may be found online in the supporting information tab for this article:

Appendix SA1: Author Matrix.

Table S1: Associations of Individual Characteristics with 30-Day Readmission, One and All Communication Attempts.