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RESEARCH ARTICLE

Reducing Readmissions among Heart Failure Patients Discharged to Home Health Care: Effectiveness of Early and Intensive Nursing Services and Early Physician Follow-Up

Christopher M. Murtaugh, Partha Deb, Carolyn Zhu, Timothy R. Peng, Yolanda Barrón, Shivani Shah, Stanley M. Moore, Kathryn H. Bowles, Jill Kalman, Penny H. Feldman, and Albert L. Siu

Objective. To compare the effectiveness of two "treatments"—early, intensive home health nursing and physician follow-up within a week—versus less intense and later postacute care in reducing readmissions among heart failure (HF) patients discharged to home health care.

Data Sources. National Medicare administrative, claims, and patient assessment data.

Study Design. Patients with a full week of potential exposure to the treatments were followed for 30 days to determine exposure status, 30-day all-cause hospital readmission, other health care use, and mortality. An extension of instrumental variables methods for nonlinear statistical models corrects for nonrandom selection of patients into treatment categories. Our instruments are the index hospital's rate of early aftercare for non-HF patients and hospital discharge day of the week.

Data Extraction Methods. All hospitalizations for a HF principal diagnosis with discharge to home health care between July 2009 and June 2010 were identified from source files.

Principal Findings. Neither treatment by itself has a statistically significant effect on hospital readmission. In combination, however, they reduce the probability of readmission by roughly 8 percentage points ($p < .001$; confidence interval = −12.3, −4.1). Results are robust to changes in implementation of the nonlinear IV estimator, sample, outcome measure, and length of follow-up.

Conclusions. Our results call for closer coordination between home health and medical providers in the clinical management of HF patients immediately after hospital discharge.

Key Words. Heart failure, hospital readmission, home health care, transitional care, instrumental variable

Heart failure (HF) is increasingly common in our aging population and difficult for patients and their clinicians to manage (Go et al. 2014; McLean and Jessup 2013). Many individuals are frequently hospitalized despite more than a decade of innovation aimed at improving the transition from hospital to home (Feltner et al. 2014) and implementation of national campaigns and financial penalties to reduce readmissions (Bradley et al. 2013; CMS.gov 2014a). Among Medicare beneficiaries, HF hospitalizations have the highest 30-day all-cause readmission rate (24.5 percent), the greatest number of readmissions (134,500), and the largest estimated total cost ($1.7 billion) among conditions with large numbers of readmissions in 2011 (Hines et al. 2014). Thus, the high readmission rate of HF patients remains a critical health care quality and cost issue, underscoring the need for successful interventions that can be rapidly disseminated into practice.

A growing number of Medicare beneficiaries hospitalized for HF are discharged to home health care (Bueno et al. 2010; Jones et al. 2015) where patients receive in-home skilled nursing and other services that might be expected to reduce readmission rates. However, the 30-day hospital readmission rate of HF patients discharged to home care is roughly 25 percent (Madigan et al. 2012). To address this persistently high rate, some agencies report providing more intensive services early in the home health episode. The evidence base for this practice is weak (Briggs Corporation 2006; Rogers, Perlic, and Madigan 2007), and a recent meta-analysis of randomized controlled trials concludes that there is low strength of evidence that "high-intensity" home-visiting programs reduce 30-day all-cause readmission (Feltner et al. 2014). Other research suggests that an early physician visit has the potential to reduce HF patient readmissions (Hernandez et al. 2010), although the potential for

Address correspondence to Christopher M. Murtaugh, Ph.D., VNSNY Center for Home Care Policy and Research, 1250 Broadway, 7th Floor, New York, NY 10001; e-mail: chris.murtaugh@vnsny.org. Yolanda Barrón, M.S., Shivani Shah, M.P.H., and Penny H. Feldman, Ph.D., are with the Center for Home Care Policy and Research, Visiting Nurse Service of New York, New York, NY. Partha Deb, Ph.D., Department of Economics, Hunter College and the Graduate Center, City University of New York, New York, NY, and NBER, Cambridge, MA. Carolyn Zhu, Ph.D., and Albert L. Siu, M.D., M.S.P.H., are with the Brookdale Department of Geriatrics and Palliative Medicine, Icahn School of Medicine at Mount Sinai, New York, NY, and James J. Peters VA Medical Center, Bronx, NY. Timothy R. Peng, Ph.D., is with the Center for Home Care Policy and Research and Business Intelligence and Outcomes, Visiting Nurse Service of New York, New York, NY. Stanley M. Moore, B.S., Bonny Doon, CA. Kathryn H. Bowles, Ph.D., is with the Center for Home Care Policy and Research, Visiting Nurse Service of New York, New York, NY, and School of Nursing, University of Pennsylvania, Philadelphia, PA. Jill Kalman, M.D., was formerly at Icahn School of Medicine at Mount Sinai, New York, NY, and is currently at Northwell Health, Lenox Hill Hospital, New York, NY.

unmeasured confounding in this observational study limits confidence in the results.

Our study employs national Medicare data and rigorous statistical methods designed to address unmeasured confounding in observational studies to advance knowledge about effective strategies for reducing the high readmission rate of HF patients discharged to home health care. Specifically, we use instrumental variables (IV) methods to compare the effectiveness of early, intensive home health nursing services and outpatient physician follow-up during the week after hospital discharge on 30-day all-cause readmission rates. We focus on postacute care shortly after discharge because it is a particularly vulnerable time for HF patients with many readmitted relatively quickly (Dharmarajan et al. 2013). We select 30-day all-cause readmission as the primary outcome since the effects of transitional care may weaken over time and because of its salience in an era of hospital financial penalties for high 30-day readmission rates.

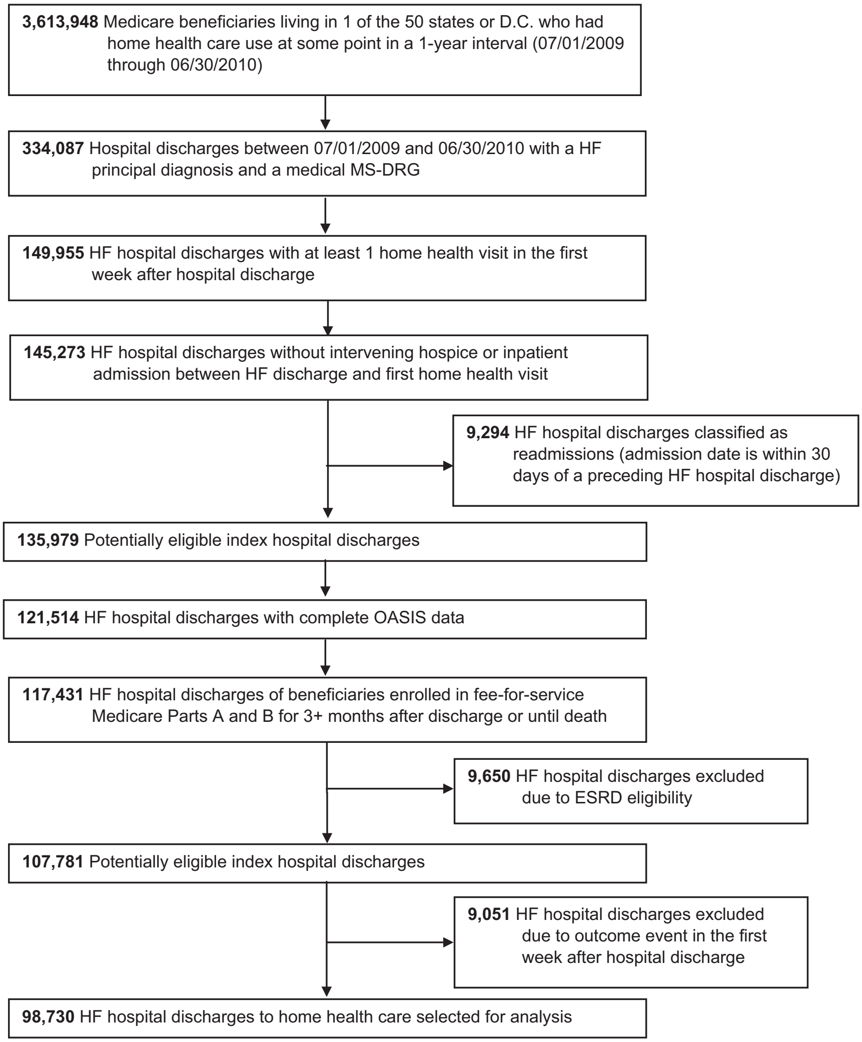
METHODS

Study Population

We use 2009 and 2010 Medicare administrative, claims, and home health patient assessment data to identify all HF hospitalizations with discharge to home health care between July 1, 2009, and June 30, 2010, and we examine health care use and mortality for 30 days after hospital discharge. The Centers for Medicare and Medicaid Services (CMS) administrative and claims files obtained for the study include the Medicare Beneficiary Summary (Enrollment) file, Medicare Beneficiary Annual Summary (chronic condition indicators) file, Medicare Provider Analysis and Review (MedPAR) file, Outpatient Standard Analytic File (SAF), Home Health SAF, Hospice SAF, and Carrier file (Part B SAF). The Outcome and Assessment Information Set (OASIS)—the comprehensive federally mandated assessment tool designed to collect nearly 100 items related to a home care patient's functional and clinical status—is a source of important patient information that is not available in Medicare administrative or claims data.

Figure 1 describes the sample selection process. Key steps include the identification of all short-term general and critical access hospital admissions with: (1) a principal diagnosis of HF using the ICD-9 CM codes employed by the federal Chronic Conditions Data Warehouse (CCW) to identify HF patients; and (2) a *medical* Medicare Severity Diagnosis Related Group (MS-DRG) ($N = 334{,}087$). HF hospitalizations assigned to a surgical MS-DRG

Figure 1: Selection of Sample ($N = 98{,}730$)



($N = 21{,}664$; data not shown) were excluded since wound care and not HF management may be the primary reason for postacute care.

A total of 149,955 HF hospitalizations were followed by a home health visit within 7 days (81.7 percent of first visits occurred within 2 days of hospital discharge). In a subsequent step, 9,294 hospitalizations with an admission date within 30 days of a preceding HF hospital discharge were not counted as index hospital stays since they represent readmissions. Exclusions include 9,650 beneficiaries receiving end-stage renal disease (ESRD) services, which may attenuate study treatment effects. We also exclude 9,051 discharges with one of the following "events" in the first 7 days after hospital discharge to home health care that preclude a full week of exposure to treatments: hospital readmission (83.7 percent), hospice admission (7.3 percent), skilled nursing or other health care facility admission (4.2 percent), or death (4.7 percent). We discuss the implications of this final exclusion at the end of the article.

Exposure to Early and Intensive Home Health Nursing and Physician Follow-Up

There is little empirical research and no universally accepted definition of what the home health industry refers to as "frontloading" of visits (O'Connor et al. 2014). We convened a panel of home health and HF experts led by a study investigator (K. B.) that considered the timing of the first nursing visit critical since postacute HF patients can deteriorate rapidly if they do not follow prescribed clinical care. The panel recommended that "early and intensive" be defined as at least one nursing visit on the day of or day after hospital discharge and at least three nursing visits (including the first visit) in the first posthospital week.

The two physician investigators (A. S. and J. K.) recommended that early physician follow-up be defined as an outpatient visit for "evaluation and management" (E&M) services—Common Procedural Terminology (CPT) codes between 992.xx and 994.xx—in the week after hospital discharge. The same CPT codes have been used by others (Hernandez et al. 2010; Sharma et al. 2009; Wolff et al. 2009). We exclude a small number of E&M visits by specialists unlikely to be managing HF (Table S1).

The four mutually exclusive treatment, or exposure, categories are as follows: (1) early and intensive home health nursing only, (2) early physician visit only, (3) both treatments, and (4) neither treatment (the reference category in our statistical models). Note that for category 3 above, there are only 89 individuals (0.72 percent of those who receive both treatments) who have a physician visit prior to the first home health nursing visit. Our analysis, therefore, does not distinguish the rare cases in the "both treatments" group where the physician visit comes before a nursing visit.

Patient Outcome Measures

Our primary outcome is 30-day all-cause hospital readmission. We follow the CMS approach to defining index HF hospital stays and 30-day all-cause hospital readmissions with an important exception. Because our objective is to compare the effectiveness of exposure to two early treatments among patients discharged to home health care, we do not count hospital readmissions that follow discharge from home health care and admission to a hospice program, skilled nursing facility (SNF), or some other inpatient setting other than a short-term general hospital (e.g., a rehabilitation facility). An example is when home health services end 15 days after hospital discharge with a patient's admission to a SNF followed a week later by hospital readmission. We do not count this type of readmission, which occurs rarely, because early treatment effects have been attenuated by services provided in another postacute care setting. Instead, we identify five mutually exclusive 30-day outcome categories based on the first "event" following home health care admission: (1) hospital readmission, (2) admission to a hospice program, (3) admission to a SNF or other inpatient care setting, (4) death, and (5) none of these events. In multivariate statistical analyses, relatively rare outcomes are combined with others to create three mutually exclusive categories: (1) hospital readmission or other health care facility admission, (2) hospice admission or death, and (3) no event (the reference category). We examine the effect of the aggregation of study outcomes into three categories in sensitivity analyses (see below).

Other Study Variables

Medicare administrative data are the source of most sociodemographic variables, although Hispanic ethnicity is from OASIS to address underreporting in administrative data. The beneficiary's ZIP code was linked to Census data to obtain the median family income in the patient's area of residence. Medicare claims during the 6 months preceding index stay discharge are the source of medical history measures including "new HF patient" (defined as no HF diagnosis on a claim up to the week prior to the index stay admission date), atrial fibrillation, acute myocardial infarction (acute MI), coronary artery bypass graft (CABG), stroke or transient ischemic attack (TIA), peripheral vascular disease, and metastatic cancer. Alzheimer's disease and related disorders (ADRD) as well as depression are CCW indicators based on a multi-year look-back period which should ameliorate underreporting on claims.

The index hospital stay claim is the source of the patient's MS-DRG: 291 (HF with major complications or comorbidities), 292 (HF with complications or comorbidities), 293 (HF without complications or comorbidities) or some other MS-DRG. It also is the source of index stay medical comorbidities (Elixhauser et al. 1998) and two services: (1) number of days in an intensive care unit and (2) number of diagnostic procedures during the index stay.

The OASIS assessment conducted shortly after hospital discharge is the source of information on respiratory status, oxygen therapy, activities of daily living (ADLs) and instrumental activities of daily living (IADLs), cognitive functioning, anxiety, and behavioral symptoms. In most cases, this is an admission OASIS assessment conducted when patients start a new episode of home health care. We also include in our analyses patients resuming a home health episode that began before the index hospital stay. A "resumption of care" OASIS assessment must be conducted at the point care resumes and the assessment is virtually identical to an admission assessment. We include a "resumption of care" indicator in multivariate analyses to control for any unmeasured differences between these two types of patients.

The reliability of OASIS items varies. Dyspnea and oxygen therapy have Kappa values of 0.42 and 1.00, respectively, when patients are observed by two different nurses at the same time. Activities of daily living all have Kappa values greater than 0.60 with the exception of grooming (Kappa = 0.50) and eating and meal preparation (Kappa = 0.38 for both). The cognitive, emotional, and behavioral items have Kappa values that range from 0.46 to 0.50 (Kinatukara, Rosati, and Huang 2005). Following the approach of Spector and Fleishman (1998), binary indicators were created for each of eight ADLs and IADLs (i.e., whether the person receives human help with the activity) and then summed to create a single scale of the number of dependencies. In addition, we created two indicators of more severe disability: (1) chairfast or bedfast and (2) human help required with both upper and lower body dressing.

Provider characteristics and contextual factors are from the CMS Provider of Services and the Area Health Resources Files (CMS.gov 2014b; HRSA.gov 2014).

Statistical Analyses

Our study design relies on observational data to assess the effect of early and intensive home health nursing and physician follow-up on hospital readmission. Both observed and unobserved characteristics can lead to biased estimates of treatment effects in observational designs due to confounding. The confounding effects of observed characteristics can be taken into account using standard regression methods, but unobserved characteristics cannot. We use the control function method, an extension of IV methods for nonlinear statistical models, to eliminate the effects of unobserved confounding (Heckman and Robb 1985; Newey, Powell, and Vella 1999). As in IV estimation, it requires the existence of at least one "instrument" that predicts assignment to treatment but is not correlated with the outcome, after taking observed characteristics into account, except via its effect on treatment.

The control function approach to estimating consistent effects of treatments on outcomes consists of two estimation stages: (1) a multinomial logit model of the four exposure categories on the IVs and the full set of observed covariates to calculate response residuals of each exposure category (i.e., observed exposure minus the predicted probability of exposure); and (2) a multinomial logit model of 30-day study outcome categories on the exposure categories, residuals from the first-stage regression (the control functions), and all covariates except the instruments. We estimate a nonlinear IV model because neither first nor second stages in this model can be linearized in a conceptually sensible way. There are four treatment possibilities; each is clinically distinct and cannot be a priori ordered. The second stage has three distinct values. While our focus is hospital readmissions, a small but substantial share of individuals die or are admitted to a hospice program. If we linearize by dropping these individuals, our estimates will suffer from sample selection bias (Angrist and Krueger 2001).

In addition to identification of instruments that predict treatment but are uncorrelated with the outcome, the correct functional form of first-stage residuals is required for the instruments to yield consistent treatment effect estimates. Our preferred specification is with residuals from the first stage included linearly in the second stage. We explore the robustness of this specification to other functional forms of the residuals as suggested by Garrido et al. (2012).

The parameters of the multinomial logit models are estimated using maximum likelihood in Stata 12.1. Standard errors of the parameters are calculated via a sandwich estimator of the covariance matrix that takes clustering of observations at the home health agency level into account.

Model of Treatment Choice. The Andersen Behavioral Model (Andersen and Newman 1973) provides the framework for the study with health care use (exposure to the treatments) modeled as a function of societal and health care system factors, and three types of individual determinants: (1) predisposing factors (e.g., age, gender, and race); (2) enabling factors (e.g., health insurance and income); and (3) need/illness level (e.g., acute and chronic disease, cognitive and physical functioning, and symptoms such as pain and anxiety). Indicators of need/illness level tend to have the greatest impact on health care use in empirical work (O'Connor et al. 2016). In our study, unmeasured aspects of patient acuity (e.g., cardiac ejection fraction) are probable confounders because, consistent with the Andersen model, they contribute to more severely ill patients being more likely to receive the treatments and to be readmitted to a hospital.

Instruments are needed, therefore, that predict selection into treatment but are uncorrelated with the likelihood of readmission except via selection into treatment. Our instruments are the index hospital's rate of early aftercare for non-HF medical patients and indicators of index hospital discharge day of the week. Both are examples of health care systems determinants in the Andersen model. Four IVs were created from sample data on each index hospital's rate of early aftercare for patients with a medical MS-DRG who did not have a principal diagnosis of HF: (1) the rate of early and intensive home health nursing only; (2) the rate of physician follow-up only; (3) the rate of both treatments; and (4) the rate of neither treatment (the reference category). We expect the rate of early follow-up instruments, as proxies for practice style at the index hospital, to predict HF patient selection into treatment. In addition, we expect a hospital's early follow-up rates, especially for non-HF admissions, to be uncorrelated with a particular HF patient's unobserved acuity.

Three IVs were created from the day of the week of index hospital stay discharge: (1) Friday, (2) Saturday or Sunday, and (3) all other days (the reference category). Home health agencies tend to have limited weekend staffing. Discharge on Friday, Saturday, or Sunday is expected to lower the probability of exposure to early and intensive home health nursing and possibly early physician follow-up.

We note that health care practice patterns and service dates have been used as instruments elsewhere (Garrido et al. 2012; Hauck and Zhao 2011; Matsui et al. 2010; Rassen et al. 2009). In our robustness checks, we estimate models with subsets of these instruments.

Interpretation of Nonlinear IV Model Results. We report marginal (incremental) effects of the exposures calculated as the average effects over the characteristics of the sample. As with all IV methods, interpretation depends on expectations about who is impacted by treatment. The local average treatment effect (LATE) is the average among those whose treatment status changes in response to the instruments. Our rate of early aftercare instruments affects treatment rates monotonically across a wide range of possible rates of treatment, suggesting that the "local" interpretation applies to a large proportion of observations in the sample (Figure S1). In sensitivity analyses, we estimate effect magnitudes separately for the treated and untreated samples to examine variation in estimated effects across sample observations.

The Visiting Nurse Service of New York IRB first approved the study in November 2011.

RESULTS

The total number of index hospital stay discharges sampled is 98,730. The great majority of beneficiaries (89.7 percent) had only one index stay in the sample, 8.8 percent had two, and 1.5 percent had three or more (data not shown). Table 1 presents the distribution of selected patient characteristics by treatment group. Sample exposure rates are 40.1 percent neither treatment, 23.0 percent nursing only, 24.3 percent physician only, and 12.6 percent both treatments. Outcomes for the full sample (bottom of Table 1) are 20.8 percent readmitted to a short-term general or critical access hospital, 0.5 percent admitted to a skilled nursing or other inpatient health care facility, 1.6 percent admitted to a Medicare hospice program, 0.9 percent died prior to any of these outcomes, and 76.2 percent had none of these events.

Baseline characteristics generally are similar across the four treatment groups, although relatively small differences are statistically significant at the $p \leq .05$ level, reflecting the very large sample size. In a multinomial logit model of outcomes on exposure indicators and observed covariates without control function adjustments, exposure to only one of the treatments has no statistically significant effect on readmission, while exposure to both treatments increases the risk of hospital readmission (Table S2).

Control Function Modeling Results

Table 2 describes the results of the first- and second-stage equations in the control function approach. The first-stage equation is the estimation of a multinomial logit model of exposures on the IVs along with observed covariates. The instruments are highly correlated with exposures (χ^2 joint test of significance is 4,529, 15 df; $p < .001$). They have the expected effect with the exception of Friday discharge which—relative to Monday through Thursday discharges—increases the probability of exposure to the treatments, in particular, the

Table 1: Sample Characteristics by Treatment Group

	Treatment Status				
	Neither	*Nursing Only*	*Physician Only*	*Both*	*All*
Index stays, no. (%)	39,617 (40.1)	22,709 (23.0)	24,007 (24.3)	12,397 (12.6)	98,730 (100.0)
Sociodemographics					
Age, mean (SD)	79.5 (10.7)	80.5 (10.0)	79.6 (10.1)	80.1 (9.7)	79.9 (10.3)
Race–ethnicity, no. (%)					
Hispanic	1,966 (5.0)	1,396 (6.2)	1,303 (5.4)	847 (6.8)	5,512 (5.6)
Non-Hispanic blacks	7,296 (18.4)	2,681 (11.8)	3,262 (13.6)	1,215 (9.8)	14,454 (14.6)
Non-Hispanic whites/other	30,355 (76.6)	18,632 (82.1)	19,442 (81.0)	10,335 (83.4)	78,764 (79.8)
Female, no. (%)	24,733 (62.4)	13,662 (60.2)	14,132 (58.9)	7,066 (57.0)	59,593 (60.4)
Annual income, mean (SD)	50,712 (20,594)	51,502 (20,176)	54,419 (21,887)	54,209 (21,163)	52,234 (20,958)
Index stay: ER admit, no. (%)	30,464 (76.9)	17,153 (75.5)	18,711 (77.9)	9,488 (76.5)	75,816 (76.8)
Recent medical history, no. (%)					
New HF patient	29,039 (26.7)	16,441 (27.6)	17,525 (27.0)	8,963 (27.7)	72,073 (27.0)
Atrial fibrillation	20,957 (52.9)	12,883 (56.7)	13,864 (57.7)	7,469 (60.2)	55,173 (55.9)
Acute MI	3,546 (9.0)	2,116 (9.3)	2,220 (9.2)	1,242 (10.0)	9,124 (9.2)
CABG	704 (1.8)	436 (1.9)	577 (2.4)	294 (2.4)	2,011 (2.0)
Stroke or TIA	4,755 (12.0)	2,679 (11.8)	2,980 (12.4)	1,464 (11.8)	11,878 (12.0)
Peripheral vascular disease	7,883 (19.9)	4,795 (21.1)	4,990 (20.8)	2,744 (22.1)	20,412 (20.7)
Metastatic cancer	1,393 (3.5)	903 (4.0)	1,228 (5.1)	611 (4.9)	4,135 (4.2)
Chronic conditions, no. (%)					
Alzheimer's disease; other dementias	11,524 (29.1)	6,363 (28.0)	6,041 (25.2)	3,083 (24.9)	27,011 (27.4)
Depression	11,452 (28.9)	6,408 (28.2)	6,890 (28.7)	3,563 (28.7)	28,313 (28.7)
Index stay MS-DRG, no. (%)					
280–282 (acute MI)	603 (1.5)	439 (1.9)	372 (1.6)	228 (1.8)	1,642 (1.7)
286–287 (HF w/cardiac catheterization)	1,277 (3.2)	815 (3.6)	867 (3.6)	567 (4.6)	3,526 (3.6)
291 (HF MCC)	13,697 (34.6)	8,236 (36.3)	8,542 (35.6)	4,579 (36.9)	35,054 (35.5)

continued

Table 1. *Continued*

	Treatment Status				
	Neither	*Nursing Only*	*Physician Only*	*Both*	*All*
292 (HF CC)	14,779 (37.3)	8,459 (37.2)	8,854 (36.9)	4,541 (36.6)	36,633 (37.1)
293 (HF no CC)	9,261 (23.4)	4,760 (21.0)	5,372 (22.4)	2,482 (20.0)	21,875 (22.2)
Index stay comorbidities, no. (%)					
Diabetes	13,354 (33.7)	7,421 (32.7)	8,002 (33.3)	3,932 (31.7)	32,709 (33.1)
Anemia	6,771 (17.1)	3,901 (17.2)	4,225 (17.6)	2,115 (17.1)	17,012 (17.2)
Chronic pulmonary disease	13,733 (34.7)	7,681 (33.8)	8,046 (33.5)	4,104 (33.1)	33,564 (34.0)
Renal failure	10,654 (26.9)	6,128 (27.0)	6,730 (28.0)	3,551 (28.6)	27,063 (27.4)
Index stay services					
Any ICU care, no. (%)	18,598 (46.9)	10,934 (48.1)	11,722 (48.8)	6,172 (49.8)	47,426 (48.0)
Any diagnostic procedures, no. (%)	5,675 (14.3)	3,595 (15.8)	3,710 (15.5)	2,057 (16.6)	15,037 (15.2)
Home care admission					
Resumption of care, no. (%)	15,686 (39.6)	8,549 (37.6)	8,733 (36.4)	4,536 (36.6)	37,504 (38.0)
Dyspnea, no. (%)					
At rest or minimal exertion	13,679 (34.5)	8,730 (38.4)	7,527 (31.4)	4,349 (35.1)	34,285 (34.7)
With moderate exertion	15,019 (37.9)	8,482 (37.4)	9,217 (38.4)	4,814 (38.8)	37,532 (38.0)
Climbing stairs	8,384 (21.2)	4,324 (19.0)	5,676 (23.6)	2,548 (20.6)	20,932 (21.2)
Not short of breath	2,535 (6.4)	1,173 (5.2)	1,587 (6.6)	686 (5.5)	5,981 (6.1)
Oxygen therapy, no. (%)	16,303 (41.2)	10,005 (44.1)	9,230 (38.4)	5,006 (40.4)	40,544 (41.1)
ADLs and IADLs, no. (%)					
0–1 limitations	8,172 (20.6)	4,233 (18.6)	5,596 (23.3)	2,613 (21.1)	20,614 (20.9)
2–3 limitations	12,363 (31.2)	6,652 (29.3)	8,113 (33.8)	4,005 (32.3)	31,133 (31.5)
4–5 limitations	11,399 (28.8)	6,739 (29.7)	6,824 (28.4)	3,687 (29.7)	28,649 (29.0)
6+ limitations	7,683 (19.4)	5,085 (22.4)	3,474 (14.5)	2,092 (16.9)	18,334 (18.6)

continued

Table 1. *Continued*

	Treatment Status				
	Neither	*Nursing Only*	*Physician Only*	*Both*	*All*
Cognitive functioning, no. (%)					
No deficit identified	21,567 (54.4)	11,844 (52.2)	14,017 (58.4)	7,005 (56.5)	54,433 (55.1)
Needs infrequent prompting	13,366 (33.7)	7,957 (35.0)	7,735 (32.2)	4,117 (33.2)	33,175 (33.6)
Needs more active direction	3,622 (9.1)	2,240 (9.9)	1,841 (7.7)	1,021 (8.2)	8,724 (8.8)
Needs considerable direction	1,062 (2.7)	668 (2.9)	414 (1.7)	254 (2.1)	2,398 (2.4)
Anxiety frequency, no. (%)					
None of the time	20,465 (51.7)	11,358 (50.0)	12,940 (53.9)	6,448 (52.0)	51,211 (51.9)
Less often than daily	11,570 (29.2)	6,714 (29.6)	6,778 (28.2)	3,562 (28.7)	28,624 (29.0)
Daily but not constantly	7,148 (18.0)	4,361 (19.2)	4,035 (16.8)	2,217 (17.9)	17,761 (18.0)
All of the time	434 (1.1)	276 (1.2)	254 (1.1)	170 (1.4)	1,134 (1.2)
Any behavior problem, no. (%)	7,594 (19.2)	4,580 (20.2)	4,120 (17.2)	2,259 (18.2)	18,553 (18.8)
30-day outcomes, no. (%)					
Hospital readmission	8,134 (20.5)	4,782 (21.1)	4,959 (20.7)	2,661 (21.5)	20,536 (20.8)
Nursing home; other facility	221 (0.6)	138 (0.6)	110 (0.5)	71 (0.6)	540 (0.5)
Hospice admission	637 (1.6)	429 (1.9)	308 (1.3)	199 (1.6)	1,573 (1.6)
Death	318 (0.8)	247 (1.1)	172 (0.7)	106 (0.9)	843 (0.9)
No events	30,307 (76.5)	17,113 (75.4)	18,458 (76.9)	9,360 (75.5)	75,238 (76.2)

Notes. ADL, activities of daily living; CABG, coronary artery bypass graft; CC, complications or comorbidities; ER, emergency room; HF, heart failure; HF w/ cardiac, heart failure with cardiac catheterization; IADL, instrumental activities of daily living; MCC, major complications or comorbidities; MI, myocardial infarction; MS-DRG, Medicare Severity Diagnosis Related Group; TIA, transient ischemic attack.

See Methods section for data sources and a description of study variables.

All differences are statistically significant at $p \leq .05$ level with the exception of anemia ($p = .373$), stroke or TIA ($p = .165$), and depression ($p = .335$).

Table 2: Control Function Regressions

	First-Stage Equation			Second-Stage Equation	
	Nursing Only	*Physician Only*	*Both*	*Rehospitalized*	*Hospice or Death*
Instruments					
Index hospital rate of early follow-up among non-HF medical patients					
Intensive home health nursing only	1.051 (0.002)***	1.000 (0.002)	1.047 (0.003)***		
Physician visit only	1.002 (0.003)	1.041 (0.002)***	1.038 (0.003)***		
Both treatments	1.048 (0.003)***	1.043 (0.003)***	1.101 (0.004)***		
Index stay discharge date					
Friday	1.182 (0.029)***	1.163 (0.026)***	1.601 (0.044)***		
Saturday or Sunday	0.557 (0.015)***	0.951 (0.021)*	0.574 (0.020)***		
Exposure categories					
Nursing treatment only				0.973 (0.181)	1.708 (0.730)
Physician treatment only				0.964 (0.212)	1.477 (0.852)
Both treatments				0.553 (0.096)***	0.329 (0.146)**
Residuals					
Residuals from first stage: nursing only				1.075 (0.201)	0.650 (0.280)
Residuals from first stage: physician only				1.061 (0.234)	0.613 (0.356)
Residuals from first stage: both treatments				1.955 (0.343)***	3.233 (1.448)**
Sociodemographics					
Age					
<65	0.935 (0.037)	0.894 (0.033)**	0.808 (0.043)***	1.125 (0.038)***	1.062 (0.128)
75–84	1.107 (0.029)***	1.051 (0.026)*	1.030 (0.033)	0.834 (0.019)***	0.946 (0.066)
85+	1.132 (0.032)***	0.952 (0.025)	0.948 (0.033)	0.763 (0.020)***	1.499 (0.104)***
Race–ethnicity					
Hispanic	0.867 (0.039)**	1.005 (0.042)	0.897 (0.052)	0.980 (0.036)	0.497 (0.065)***
Non-Hispanic blacks	0.775 (0.024)***	0.818 (0.023)***	0.713 (0.028)***	1.026 (0.028)	0.557 (0.046)***
Female	0.935 (0.017)***	0.923 (0.016)***	0.882 (0.020)***	0.920 (0.016)***	0.680 (0.030)***
Median household income (in $5,000s)	1.006 (0.003)*	1.014 (0.002)***	1.017 (0.004)***	0.995 (0.002)*	1.012 (0.006)*
Index stay admission via ER	0.942 (0.021)**	0.966 (0.021)	0.926 (0.027)**	1.073 (0.022)***	1.015 (0.053)

continued

Table 2. *Continued*

	First-Stage Equation			*Second-Stage Equation*	
	Nursing Only	*Physician Only*	*Both*	*Rehospitalized*	*Hospice or Death*
Recent medical history					
Heart failure (not a new HF patient)	0.975 (0.020)	1.026 (0.020)	0.975 (0.025)	1.405 (0.029)***	1.449 (0.077)***
Atrial fibrillation	1.088 (0.020)***	1.151 (0.020)***	1.218 (0.028)***	1.178 (0.020)***	1.004 (0.046)
Acute myocardial infarction	1.022 (0.033)	0.986 (0.031)	1.077 (0.044)	1.265 (0.035)***	1.049 (0.081)
Coronary artery bypass graft	1.145 (0.073)*	1.240 (0.071)***	1.238 (0.092)**	0.786 (0.045)***	0.400 (0.100)***
Stroke/transient ischemic attack	1.006 (0.028)	1.116 (0.030)***	1.069 (0.038)	1.055 (0.026)*	0.963 (0.064)
Peripheral vascular disease	1.068 (0.024)**	1.083 (0.022)***	1.150 (0.032)***	1.137 (0.022)***	1.115 (0.059)*
Metastatic cancer	1.069 (0.058)	1.266 (0.061)***	1.217 (0.078)**	1.203 (0.054)***	1.383 (0.147)**
Chronic condition warehouse indicator					
Alzheimer's disease or related disorder	0.915 (0.020)***	0.881 (0.019)***	0.841 (0.025)***	1.226 (0.024)***	0.968 (0.050)
Depression	0.957 (0.019)*	1.051 (0.020)**	1.016 (0.026)	1.254 (0.023)***	0.819 (0.042)***
Index stay MS-DRG					
280–282 (acute MI)	1.148 (0.081)*	1.005 (0.071)	1.073 (0.097)	1.036 (0.066)	1.159 (0.174)
286–287 (HF w/cardiac catheterization)	1.136 (0.056)**	1.041 (0.051)	1.297 (0.075)***	1.022 (0.045)	0.624 (0.106)**
292 (HF CC)	0.978 (0.021)	0.964 (0.020)	0.948 (0.024)*	0.971 (0.018)	0.936 (0.047)
293 (HF no CC)	0.899 (0.023)***	0.964 (0.024)	0.856 (0.027)***	0.873 (0.021)***	0.806 (0.055)**
Index stay comorbidities					
Metastatic cancer	1.067 (0.115)	1.496 (0.142)***	1.328 (0.164)*	1.436 (0.124)***	2.540 (0.443)***
Lymphoma	1.067 (0.102)	1.587 (0.131)***	1.321 (0.143)**	1.163 (0.094)	1.318 (0.256)
Solid tumor without metastasis	1.005 (0.073)	1.153 (0.078)*	1.086 (0.096)	1.243 (0.077)***	2.002 (0.251)***
Diabetes	1.036 (0.020)	1.044 (0.019)*	1.009 (0.025)	1.010 (0.018)	0.765 (0.039)***
Fluid and electrolyte disorders	1.061 (0.023)**	1.065 (0.022)**	1.105 (0.029)***	1.083 (0.021)***	1.197 (0.062)***
Obesity	1.044 (0.035)	0.924 (0.031)*	0.930 (0.041)	0.785 (0.026)***	0.602 (0.067)***
Deficiency anemia	1.007 (0.024)	1.050 (0.023)*	1.012 (0.029)	1.047 (0.022)*	1.010 (0.056)
Coagulopathy	1.077 (0.058)	1.054 (0.054)	1.235 (0.076)***	1.152 (0.052)**	1.192 (0.150)

continued

Table 2. *Continued*

	First-Stage Equation			*Second-Stage Equation*	
	Nursing Only	*Physician Only*	*Both*	*Rehospitalized*	*Hospice or Death*
Paralysis	0.947 (0.061)	0.864 (0.060)*	0.749 (0.068)***	0.840 (0.053)**	0.666 (0.105)**
Other neurological disorders	0.906 (0.036)**	0.966 (0.039)	0.924 (0.050)	0.904 (0.035)**	0.803 (0.078)*
Hypertension	0.977 (0.018)	1.018 (0.017)	0.994 (0.022)	0.945 (0.016)***	0.842 (0.037)***
Chronic pulmonary disease	0.942 (0.018)**	0.968 (0.018)	0.928 (0.023)**	1.061 (0.019)***	0.907 (0.043)*
Liver disease	0.930 (0.084)	1.045 (0.081)	0.809 (0.089)*	1.324 (0.093)***	1.060 (0.240)
Renal failure	0.997 (0.020)	1.034 (0.020)	1.055 (0.027)*	1.205 (0.022)***	1.325 (0.064)***
Weight loss	1.093 (0.058)	0.987 (0.054)	0.984 (0.066)	1.105 (0.054)*	1.223 (0.128)*
Index stay days in ICU					
1–2 days in ICU	0.972 (0.029)	1.060 (0.029)*	0.995 (0.038)	0.979 (0.025)	1.031 (0.071)
3–4 days in ICU	1.012 (0.028)	1.028 (0.025)	1.016 (0.035)	1.003 (0.023)	1.011 (0.064)
5–6 days in ICU	1.111 (0.037)***	1.006 (0.032)	1.090 (0.044)*	1.058 (0.030)*	1.009 (0.079)
7+ days in ICU	1.213 (0.043)***	0.970 (0.033)	1.156 (0.050)***	1.131 (0.033)***	0.951 (0.075)
Number of index stay diagnostic procedures					
1 Procedure	1.038 (0.027)	1.027 (0.026)	1.037 (0.034)	1.070 (0.026)**	0.987 (0.061)
2+ Procedures	1.070 (0.072)	0.96 (0.062)	1.084 (0.086)	1.216 (0.068)***	1.074 (0.153)
OASIS: resumption of care	0.942 (0.019)**	0.963 (0.018)*	0.976 (0.024)	1.129 (0.020)***	1.144 (0.054)**
Frequency of dyspnea					
At rest (during day or night)	1.189 (0.047)***	1.000 (0.039)	1.186 (0.059)***	1.367 (0.046)***	1.537 (0.131)***
With minimal exertion	1.161 (0.031)***	1.005 (0.025)	1.164 (0.039)***	1.193 (0.028)***	1.281 (0.087)***
With moderate exertion	1.066 (0.025)**	1.008 (0.022)	1.099 (0.032)***	1.063 (0.022)**	1.027 (0.065)
Receiving oxygen in home	1.082 (0.021)***	0.929 (0.018)***	0.977 (0.025)	1.121 (0.021)***	1.413 (0.066)***
Sum of ADLs and IADLs (range 0–8)					
1	1.121 (0.046)**	1.052 (0.040)	1.155 (0.057)**	1.031 (0.039)	1.184 (0.198)
2	1.147 (0.048)***	1.050 (0.040)	1.182 (0.059)***	1.022 (0.038)	1.538 (0.246)**
3	1.122 (0.049)**	1.024 (0.042)	1.200 (0.063)***	1.082 (0.042)*	1.987 (0.316)***

continued

Table 2. *Continued*

	First-Stage Equation			Second-Stage Equation	
	Nursing Only	*Physician Only*	*Both*	*Rehospitalized*	*Hospice or Death*
4	1.206 (0.055)***	1.044 (0.044)	1.243 (0.068)***	1.126 (0.046)**	2.012 (0.330)***
5	1.284 (0.063)***	0.980 (0.044)	1.218 (0.071)***	1.121 (0.049)**	2.540 (0.414)***
6	1.361 (0.071)***	0.902 (0.046)*	1.222 (0.079)**	1.107 (0.052)*	3.154 (0.524)***
7+	1.491 (0.102)***	0.812 (0.058)**	0.995 (0.091)	1.189 (0.075)**	4.793 (0.893)***
Mobility					
Some impairment	0.934 (0.036)	0.847 (0.030)***	0.772 (0.033)***	1.048 (0.038)	1.192 (0.173)
Chair/bedfast	1.077 (0.065)	0.587 (0.039)***	0.620 (0.049)***	1.221 (0.070)***	1.990 (0.333)***
Dressing—Human help required with upper and lower body dressing	1.011 (0.028)	0.968 (0.025)	1.025 (0.034)	1.122 (0.027)***	1.475 (0.099)***
Cognitive function					
Needs infrequent prompting	0.991 (0.021)	0.957 (0.020)*	0.937 (0.024)**	1.023 (0.020)	1.060 (0.057)
Needs more active direction	0.989 (0.036)	0.913 (0.033)**	0.910 (0.042)*	0.919 (0.030)**	1.266 (0.095)**
Needs considerable direction	0.925 (0.059)	0.850 (0.057)*	0.921 (0.076)	0.870 (0.050)*	1.484 (0.157)***
Anxious					
Less often than daily	1.012 (0.022)	0.985 (0.020)	1.000 (0.027)	1.036 (0.020)	1.029 (0.053)
Daily, but not constantly	1.021 (0.027)	0.969 (0.025)	0.989 (0.033)	1.082 (0.024)***	1.088 (0.065)
All of the time	1.073 (0.090)	0.977 (0.086)	1.213 (0.123)*	1.211 (0.087)**	1.470 (0.244)*
Disruptive behavior	1.001 (0.026)	1.003 (0.025)	0.990 (0.031)	0.947 (0.021)**	0.907 (0.051)
	N = 98,730			N = 98,730	

Notes. ADL, activities of daily living; CC, complications or comorbidities; ER, emergency room; HF, heart failure; HF w/ cardiac, heart failure with cardiac catheterization; IADL, instrumental activities of daily living; ICU, intensive care unit; MCC,major complications or comorbidities; MI, myocardial infarction; MS-DRG, Medicare Severity Diagnosis Related Group; OASIS, Outcome and Assessment Information Set.
Cluster-robust (home health agency level) standard errors are in parentheses. Thirty-day outcome reference category is "no event" during the follow-up period. Control function adjustment for endogenous treatment. State-level dummy variables omitted from table.
*$p \leq .05$, **$p \leq .01$, ***$p \leq .001$.

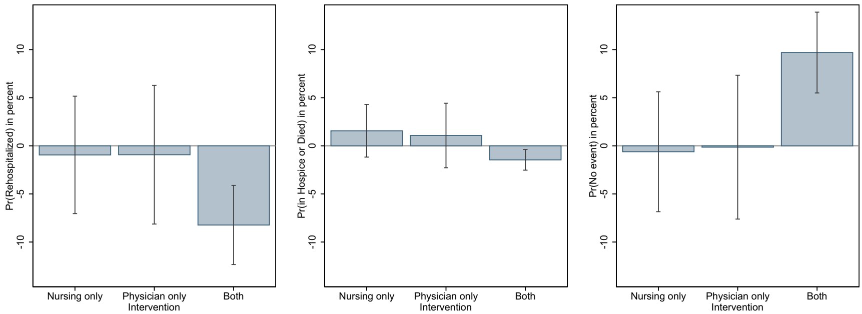
combination of both treatments ($p < .001$). Other notable first-stage regression results include the consistently lower exposure to treatments of non-Hispanic blacks relative to whites and others and persons with ADRD relative to others ($p < .001$). However, persons with a history of atrial fibrillation had a consistently higher exposure to each of the treatments relative to others ($p < .001$).

The second-stage equation, on the right side of Table 2, is the estimation of a multinomial logit model of 30-day outcomes on exposure categories and residuals along with observed covariates. The residuals are jointly significant (χ^2 joint test of significance is 26.76, 6 df; $p < .001$), indicating the existence of unobserved confounding. Exposure to the combination of both treatments, relative to exposure to neither treatment, substantially reduces the probability of hospital readmission ($p < .001$) as well as admission to a hospice or death ($p = .01$) versus no "event." Other notable second-stage regression results include no greater risk of hospital readmission for minorities, after adjusting for treatment exposure and other covariates, but they are less likely to be admitted to a hospice program or die during the 30-day follow-up period relative to whites and others ($p < .001$). A large number of medical conditions and HF severity (as captured by the MS-DRG) increase both the risk of hospital readmission and hospice admission or death, relative to those without the conditions, as do dyspnea, oxygen therapy, and higher levels of functional impairment.

Figure 2 presents the risk-adjusted local average incremental treatment effect (LATE) of early and intensive home health nursing care and physician follow-up on 30-day all-cause hospital readmission in the left-most panel. Neither treatment by itself has an effect on readmission. The two treatments together, however, reduce the probability of 30-day all-cause hospital readmission for a substantial share of the sample by roughly 8 percentage points ($p < .001$; confidence interval = -12.3, -4.1). Chi-square tests of the difference between the combined treatment effect and each treatment effect by itself are close to conventional levels of statistical significance ($p = .06$ for both tests), suggesting that the effect of the two treatments is not just additive (i.e., the interaction of the two treatments contributes to the large joint effect).

The remaining panels of Figure 2 show risk-adjusted local average incremental treatment effects on the two other outcomes. The two treatments together reduce the probability of hospice admission or death for a substantial share of the sample by a small amount (approximately 1.5 percentage points; $p = .007$). They also have a large positive effect on the probability of "no

Figure 2: Incremental Treatment Effects with 95 Percent Confidence Intervals on 30-Day Rehospitalizations and Other Events [Color figure can be viewed at wileyonlinelibrary.com]



Note. Estimates from a multinomial logit model with control function adjustment for endogenous treatment.

event" during the follow-up period consistent with their negative effect on each of the other outcomes ($p < .001$).

Sensitivity Analyses. The first row of Table 3 reports the point estimates, confidence intervals, and *p*-values for the hospital readmission results described graphically in Figure 2. Subsequent rows report sensitivity analysis results for the same set of parameters; specifically: (1) estimates of local average treatment effects among treated (LATT) and untreated (LATU) patients in the top panel; (2) results from alternative IV and control function specifications in the middle panel; and (3) estimates from other sample and outcome modifications in the bottom panel. The results of these robustness checks are qualitatively the same and, in most cases, very close to the estimates from our preferred approach (first row of Table 3). A more complete description of sensitivity analysis results is available in the online Appendix.

CONCLUSIONS

The combination of early, intensive nursing services and at least one outpatient physician visit in the week after hospital discharge reduces the risk of 30-day hospital readmission for a substantial share of Medicare HF patients

Table 3: Sensitivity of Treatment Incremental Effects on Hospital Readmission to Alternative Sample, Instrument, and Control Function Specifications

	Nursing Intervention Only		Physician Intervention Only		Both Interventions	
	Percentage Point Change (95% CI)	*p Value*	*Percentage Point Change (95% CI)*	*p Value*	*Percentage Point Change (95% CI)*	*p Value*
LATE sample of 98,730 index stays and 21,076 hospital readmissions	−0.90 (−7.00, 5.21)	.77	−0.92 (−8.12, 6.29)	.80	−8.23 (−12.34, −4.12)	<.001
LATT sample of 12,397 index stays and 2,732 hospital readmissions	—		—		−9.95 (−17.05, −2.85)	<.001
LATU sample of 39,617 index stays and 8,355 hospital readmissions	−0.82 (−6.55, 4.92)	.78	−0.85 (−7.60, 5.91)	.81	−7.77 (−11.59, −3.95)	.006
LATE sample with instrument modification						
Omit hospital follow-up rate instruments	0.94 (−12.87, 14.76)	.89	−15.47 (−35.17, 4.23)	.12	−12.50 (−24.65, −0.36)	.044
Omit index stay discharge day instruments	−2.86 (−9.58, 3.86)	.40	−2.08 (−9.82, 5.66)	.53	−8.24 (−13.01, −3.47)	.001
Add interactions of hospital follow-up rates	−2.48 (−9.21, 4.25)	.47	−1.92 (−9.67, 5.83)	.63	−8.45 (−13.17, −3.74)	<.001
Add squared terms of residuals (quadratic control function)	−1.81 (−8.10, 4.47)	.57	−1.13 (−8.51, 6.24)	.76	−9.40 (−14.01, −4.75)	<.001
LATE sample with index stay exclusions						
Omit 3,114 critical access hospital discharges	0.97 (−5.47, 7.42)	.77	0.82 (−6.86, 8.50)	.83	−8.29 (−12.42, −4.17)	<.001
Omit 7,222 discharges of persons <age 65	−2.68 (−8.84, 3.48)	.39	−3.44 (−10.71, 3.83)	.35	−7.47 (−11.92, −3.01)	.001
Omit 3,772 discharges where LOS ≤1 day or ≥30 days	−0.85 (−7.01, 5.32)	.79	−0.86 (−8.24, 6.52)	.82	−8.50 (−12.66, −4.33)	<.001
LATE sample with follow-up event exclusions						
Omit 1,001 “planned” hospital readmissions	−0.01 (−6.14, 6.11)	.99	−0.30 (−7.52, 6.91)	.93	−8.93 (−12.74, −5.12)	<.001
Omit 540 SNF and other facility admissions	−0.77 (−6.84, 5.29)	.80	−0.85 (−7.99, 6.29)	.82	−7.93 (−12.00, −3.86)	<.001

continued

Table 3. *Continued*

	Nursing Intervention Only		*Physician Intervention Only*		*Both Interventions*	
	Percentage Point Change (95% CI)	*p Value*	*Percentage Point Change (95% CI)*	*p Value*	*Percentage Point Change (95% CI)*	*p Value*
LATE sample splitting hospice and death outcomes in the multinomial logit	−0.89 (−6.99, 5.22)	.78	−0.95 (−8.16, 6.25)	.80	−8.22 (−12.33, −4.11)	<.001
LATE sample lengthening follow-up period to 37 days (inclusion of 4,758 day 31–37 events)	−2.03 (−8.37, 4.30)	.53	−2.10 (−9.68, 5.47)	.59	−7.78 (−12.58, −2.95)	.002

Notes. Control function adjustment for endogenous treatment. Except where indicated: "hospital readmissions" include a relatively small number of admissions to other inpatient settings (e.g., SNFs); and the instruments are index hospital rates of early follow-up for non–heart failure medical patients and day of the week of index hospital stay discharge (see Methods section).

LATE, local average treatment effects among all patients; LATT, local average treatment effects among patients receiving treatment; LATU = local average treatment effects among patients receiving neither treatment (untreated).

[Correction added on 15 August 2016, after first online publication: layout errors in Tables 1–3 have been corrected, and additional corrections in column and row descriptions in Table 2 have been incorporated.]

discharged to home health care. The 95 percent confidence interval around the point estimate of the effect of joint nursing and physician treatment (−12.3, −4.1) should be the focus when interpreting our results due to imprecision inherent to the IV method (Murray 2006). The upper limit is a reduction of roughly 4 percentage points—or 20 percent—in the risk of readmission. This very conservative estimate still is large and falls between the effect sizes reported by Feltner et al. (2014) for the two studies identified with information on 30-day all-cause hospital readmission in their systematic review of HF transitional care clinical trials. The first trial (Naylor et al. 2004) examined the impact of a high-intensity intervention led by advanced practice nurses with eight planned home visits, the first within 24 hours of hospital discharge (30-day readmission rates were 10.2 and 29.8 percent for intervention and control groups, respectively; RR = 0.34; CI = 0.19, 0.62). The other trial (Jaarsma et al. 1999) included one telephone call within 7 days and one home visit within 10 days of discharge and had no statistically significant effect on 30-day readmission rates (RR = 0.89; CI = 0.43, 1.85).

The study sample, while large, includes only patients receiving at least one home health visit in the week after hospital discharge who do not have an "event" in that week (e.g., hospital readmission and death) that precludes a full week of exposure to the postacute treatments. We also exclude ESRD beneficiaries because they are likely to be receiving at least some nursing services independent of home health care. The relatively large number of readmissions in the week after hospital discharge (7,574) raises important questions about the reasons for their readmission and the extent to which they differ from later readmissions. No major differences have been found in our own analyses (Jarrin et al. 2014), which is consistent with another recent study of national Medicare data (Dharmarajan et al. 2013). More work is needed to better understand the reasons for rapid readmissions and how to prevent them as well as how to reduce the high rate of readmission among ESRD beneficiaries (USRDS.org 2012).

Despite these exclusions, there are more than 20,000 readmissions between the 8th and 30th days postdischarge in our national sample. They represent 15.3 percent of all readmissions of Medicare beneficiaries following a HF hospitalization based on AHRQ's figure of 134,500 readmissions in 2011 (Hines et al. 2014). Only 12.9 percent receive both treatments, suggesting that a substantial number of readmissions within 30 days could be avoided if both services were more widely provided.

Wider adoption of the combination of treatments hinges, in part, on timely action during the hospital stay. Early referral and transfer of key patient information to home care agencies is critical to their providing nursing visits shortly after discharge. Agency staff will need to work with the referring physician, the patient, and family to arrange an early physician visit if none is scheduled. While increasing these visits may be challenging given the difficulty beneficiaries have leaving home, our results are not predicated on follow-up by a specialist or the same physician who provided hospital care. Neither are significant factors in prior work (Hernandez et al. 2010), suggesting that home health agency medical staff as well as physician home-visit programs could provide the necessary medical oversight when patients cannot leave home.

Our study highlights the importance of control function or IV analysis to correct for the nonrandom assignment of individuals to different treatment groups when employing observational data. Our regression estimates without control function adjustments indicate that exposure to both treatments increases the risk of hospital readmission. In contrast, the control function analysis shows that readmissions would decline if the two treatments were more widely provided to the sample as a whole, assuming a local average treatment effect. The prior study reporting that an early physician visit reduces the risk of hospital readmission relied on traditional regression methods and acknowledged that potential confounding is a study limitation but did not otherwise address the issue (Hernandez et al. 2010). IV estimation methods, however, are designed to take unobserved characteristics into account and strengthen confidence in causal inferences based on observational data.

At the same time, we acknowledge the inherent uncertainty in the control function approach, as in all IV methods, concerning who is impacted by treatment. Our index hospital early aftercare rate instruments affect postacute treatment rates monotonically across a wide range of possible IV values, suggesting that the local average treatment effect interpretation applies to a large proportion of the sample. In addition, we find in sensitivity analysis that results are remarkably similar regardless of the assumption about the population impacted, suggesting that the treatments have similar impacts across a broad range of patients. Nevertheless, we cannot say precisely how many people in our sample we expect to benefit from exposure to both treatments.

We also recognize that threats remain to the validity of study findings. One uncertainty is whether our IVs affect outcomes only through their impact on exposure to treatment. One could argue that our practice style instruments are correlated with unobserved hospital quality, which is the source of endogeneity, rather than patient acuity, with hospitals providing better care more likely to schedule early follow-up and have better outcomes. But without control function adjustments for endogeneity, nursing and physician treatments by themselves have no statistically significant effects on readmission while exposure to both treatments increases the risk of hospital readmission. This makes it very unlikely that unobserved hospital quality is the source of potential endogeneity, while strengthening the case for endogeneity because of unobserved patient acuity. Nevertheless, we estimated a model with only day-of-the-week instruments and obtain very similar estimates, albeit with larger standard errors.

Similarly, if the day of the week of hospital discharge is a function of clinical expectations about the risk of readmission as opposed to other factors (e.g., day of the week of admission, hospital staffing and work flow), the assumption that the impact of an IV on patient outcomes is only through its impact on exposure to treatment would be violated. However, eliminating day of the week instruments leads to parameter estimates that are very similar in magnitude and statistical significance.

In conclusion, our results indicate that the combination of early and intensive home health nursing services and at least one physician follow-up visit in the week after hospital discharge have the potential to reduce the risk of readmission for a substantial share of Medicare HF patients discharged to home health care. This is a large and growing group, although a recent breakthrough in pharmacologic treatment of HF patients could restrain growth over time depending on whether the results of the clinical trial—which enrolled a predominantly male, relatively young sample of patients with reduced ejection fraction—are achieved in real-world Medicare beneficiary practice (McMurray et al. 2014). In any case, our results call for closer coordination between medical and home health providers in the clinical management of HF patients immediately after hospital discharge. Together, medical and home health providers can achieve the goal of improving HF patient care by avoiding costly hospital readmissions.

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Supporting Information

Additional supporting information may be found in the online version of this article:

Appendix SA1: Author Matrix.

Appendix SA2: Sensitivity Analyses.

Table S1: Physician Specialties Included and Excluded When Identifying Outpatient Visits within 1 Week of Index Hospital Stay Discharge.

Table S2: Model of 30-Day Outcomes without Control Function Adjustments.

Figure S1: Predicted Treatment Rates as Index Hospital Early Follow-Up Rates Increase.