Supplementary Online Content

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This supplementary material has been provided by the authors to give readers additional information about their work.

eAppendix. Methods

Data

We used Medicare claims data to observe all fee-for-service Medicare-reimbursed hospitalizations and post-acute care use in the U.S. between 2010 and 2016. We used the 100% MedPAR file, which include hospital claims for all fee-for-service Medicare beneficiaries as well as information-only claims for Medicare Advantage enrollees from hospitals that received disproportionate-share hospital or medical education payments from Medicare.[13] Prior work has shown that these claims include 92% of all Medicare discharges.[14] We also used fee-for-service SNF claims and home health claims to determine Medicare fee-for-service payment. We used Medicare assessment data from home health and SNF to identify post-hospital-discharge use of home health and SNF (using the Outcome and Assessment Information Set and Minimum Data Set, respectively). These assessment data are completed regardless of insurer and therefore include both fee-for-service and Medicare Advantage enrollees. These assessment data were also used to measure functional improvement over their post-acute care episode. The data were supplemented with the Medicare Beneficiary Summary File, which contains information on beneficiary enrollment in Medicare and demographics including date of birth, sex, and race, and date of death.

Study sample

We included all patients discharged from an acute care or critical access hospital home with visits from a home health agency or to SNF. We identified these discharges by linking hospital discharge claims to home health and SNF assessment data with a start date within 3 days of hospital discharge. We included beneficiaries age 66 or older at hospital admission. We

excluded beneficiaries who had been in a nursing home in the 30 days prior to hospitalization (as they are more likely to go back to the nursing home independent of other factors), whose hospital length of stay was less than three days (the minimum stay required for a SNF admission to be covered by Medicare), or discharged to hospice.

Study variables

Outcome measures

Our primary outcome measure was readmission within 30 days of hospital discharge. We followed Medicare's definition of hospital readmission from the Hospital Readmission Reduction Program, which includes unplanned readmissions to any acute care hospital within 30 days of discharge from an index hospitalization. Planned readmissions include those for bone marrow or solid organ transplant, maintenance chemotherapy, rehabilitation, or a potentially planned procedure not performed to treat an acute condition or a complication of previous care.

We included several additional outcomes. We measured mortality within 30 days of hospital discharge using data from the Medicare Beneficiary Summary File. We also measured improvement in functional status over the post-acute care episode using clinical assessment data from home health and SNFs. To measure improvement in functional status, we created a six-point activities of daily living scale, which is measured for each patient on admission and again on discharge. Patients receive one point for each of six activities in which they can function independently: bathing, dressing, toileting, transferring, continence, and feeding.[1] A

positive change in the number of independent activities between admission and discharge is an indicator of improvement in functional status. Finally, we measured Medicare payment for fee-for-service beneficiaries using three variables: (1) Medicare payment for the index hospitalization; (2) Medicare payment to the first home health agency or SNF for post-acute care following hospital discharge; and (3) total Medicare payment in the first 60 days following hospital admission. This last payment variable includes payment for hospitalization, post-acute care use, and any readmission or subsequent post-acute care use within 60 days from admission to the index hospitalization. Payment information is not available for Medicare Advantage enrollees.

Covariates

We adjusted for patient-level covariates in all regressions, including age, sex, race, and 31 indicators of comorbidities. Comorbidities were defined based on CMS Hospital Readmission Reduction Program specifications for risk adjustment of readmission and are measured over the one year prior to hospital admission. They included: severe infection; other infectious disease pneumonias; metastatic cancer/acute leukemia; severe cancer; other cancers; diabetes mellitus; protein-calorie malnutrition; end-stage liver disease; severe hematological disorders; alcohol abuse; psychiatric comorbidity; hemiplegia, paraplegia, paralysis, functional disability, seizure disorders, CHF, coronary atherosclerosis or angina/CVD; specified arrhythmias; COPD; fibrosis of lung or other chronic lung disorders; dialysis; decubitus ulcer or chronic skin ulcer; septicemia/shock; disorders of fluid, electrolyte, acid-base; iron deficiency or other unspecified anemias; cardiorespiratory failure or shock; acute renal failure; pancreatic disease; rheumatoid

arthritis; respiratory dependence/tracheostomy; transplant; coagulation defects/hematologic disorders; hip fracture/dislocation. We also adjusted for the diagnosis related group (DRG) of each discharge using a dummy variable for each DRG. Finally, we included year fixed effects and hospital fixed effects in all regressions.

We included additional covariates for regressions estimating the effect of post-acute care on two outcomes. First, for regressions estimating the effect on 30-day readmission we accounted for censoring by patient death by adjusting for the number of days each person is observed in that 30-day period, where patients who die in the first 30 days following discharge have a value of less than 30. Second, for regressions estimating the effect on improvement in functional status, we adjusted for the level of functional status on admission to post-acute care and the number of days in the post-acute care episode.

Instrumental variable

In instrumental variables analyses, the instrument approximates random assignment of patients to treatment groups, in our case to home health versus SNF. We used differential distance as our instrument, a commonly used approach. Distances were calculated using linear arc distances, which measures the number of miles between the centroids of two ZIP codes. We calculate differential distance as the difference between (1) the distance from a patient's ZIP code of residence to the nearest home health agency and (2) the distance from a patient's ZIP of residence code to the nearest SNF (see supplemental Table 1 for summary of differential distance). Unlike in SNFs, where the patient and family bear the burden of travel, in home

health they do not. Nonetheless, home health agencies do bear the costs of that travel and are more likely to locate in an area close to where they deliver most of their care. Thus, we consider the differential distance between home and home health versus SNF to be a proxy for the relative local supply of home health and SNF.

We used differential distance to create a dichotomous measure which equals one if the beneficiary lives closer to a home health agency than a SNF and zero if the beneficiary lives equidistant between a home health agency and SNF or closer to a SNF than to a home health agency (supplemental Table 2). The median patient lived in the same ZIP code as a SNF. The median differential distance was also zero. We dichotomized differential distance because the relationship between provider choice and distance is not linear. When the differential distance was negative (indicating living closer to a home health agency) it was the strongest predictor of treatment choice. Further, the effect of differential distance on treatment choice did not increase as the distance to home health relative to SNF increased (though it remained strongly predictive of treatment choice). This could be because distance from a patient's home to a home health agency is an imperfect proxy for local supply, or because selection on perceived treatment effects if the treatment effect is heterogeneous.[2] If it is the latter driving the relationship, the continuous instrument would violate the monotonicity assumption underlying instrument validity. By using the binary indicator of living closer to a home health agency than SNF, the monotonicity assumption is much more likely to be met.[2] While the lack of monotonicity suggests that the relationship between differential distance and treatment option is complex, , it does not invalidate the use of differential distance as an instrument.

We first tested whether the instrument was correlated with the treatment of interest, in this case treatment by a home health agency (rather than a SNF). Using linear regression, we predict discharge to home health (versus SNF) as a function of whether the beneficiary lives closer to a home health agency than to a SNF and include a full set of covariates (age, sex, race, the 31 indicators of comorbidities described above, dummy variables for each DRG, year fixed effects, and hospital fixed effects). We found that living closer to a home health agency was highly predictive of discharge to a home health agency (F-statistic = 263.4; supplemental Table 3). F-statistics over ten are generally considered strong.[3] Indeed, the probability of receiving care from a home health agency is 3.6 percentage points higher among patients who live closer to a home health agency than a SNF (42.1% versus 38.4%).

While we cannot directly assess the relationship between the instrument and unmeasured confounders, we next examined the relationship between the instrument and measured confounders. If measured confounders are balanced across the instrument, we assume that unmeasured confounders are as well. We find that most patient covariates are balanced across values of the instrument (supplemental Table 4). The exception is race, where we find that a higher portion of patients living closer to home health agencies are black and Hispanic. Differences in race are often observed across distance-based instrumental variables.[4,5] We account for these imbalances by adjusting for them in the instrumental variable model, as the instrumental variable is valid if it is uncorrelated with unobserved confounders, conditional on observable confounders.

We conducted a falsification test of our instrument, examining the effect of the instrument on Medicare beneficiaries who are hospitalized far from home (i.e., "vacationers").[5,6] The local supply of home health and SNF surrounding a person's primary residence should not affect the decision to discharge to home health versus SNF for those who enter a hospital far from their primary residence, since the supply around the hospital is the relevant constraint. For this sub-sample, we thus expect the first stage to be weak and the effect of the instrument to be closer to zero. To implement this, we test the predictive strength of the instrument among Medicare beneficiaries hospitalized more than 75 miles from home (4.3% of the sample) and those hospitalized more than 150 miles from home (2.6% of the sample). These results suggest a weak instrument in these samples of vacationers as individuals are hospitalized farther from home (see supplemental Table 3). In addition, the decline in the strength of our instrument suggests that where people live relative to SNF and home health agency location is uncorrelated with other unobservable factors that determine treatment choice.

Statistical analysis

We first tested for differences in patient outcomes using ordinary least squares regression, adjusting for the covariates described above. Then, in the instrumental variable analysis, 2-stage least squares regressions (2SLS) were performed where the first stage predicted the effect of the instrument on admission to a home health agency following hospital discharge and the second stage estimated the effect of predicted admission to home health from the first

stage on the outcomes of interest. Both stages adjusted for covariates as described above and adjusted the standard errors for clustering within hospital.

Additional analyses

First, to test the robustness of the estimated effect of home health on readmission rates, we re-estimated this effect in the following subgroups of readmissions. First, we categorized readmissions as those that were for non-discretionary diagnoses and those that were potentially discretionary.[7] Conceptually, we define potentially discretionary hospitalizations as those resulting from conditions with greater uncertainty in the optimal treatment and thus greater variation in the use of hospital admission, whereas nondiscretionary hospitalizations are those resulting from conditions or events for which a hospital admission is almost always advised, as no other setting would typically have the required resources to address the acute needs. To categorize readmissions into potentially discretionary and nondiscretionary groups, we drew on prior work,[8,9] which used the degree of variability in hospitalizations to assess the degree of potential discretion. Nondiscretionary readmissions included those for the following conditions: Acute myocardial infarction, cerebrovascular disorders, hip repair, inguinal and femoral hernia repair, major bowel operation, cholecystectomy, gastrointestinal bleed, appendectomy, respiratory failure, and severe infection. All others are classified as potentially discretionary. We expect any difference in readmission rates between those discharged to home health and those discharged to SNF to be concentrated in the discretionary readmissions whereas we do not expect any difference in rates of non-discretionary readmissions.

Then, we tested the robustness of the results in the following subgroups: 1) among the twenty most common DRGs being discharged to post-acute care, grouping DRGs into those for medical conditions versus surgical/rehabilitation (a full list of these DRGs is available in supplemental Table 5); 2) fee-for-service enrollees; 3) Medicare Advantage enrollees; 4) in urban areas; and 5) in hospitals that were not vertically integrated with a SNF or a home health agency.

Additionally, because the outcome of readmission is censored at death, we re-estimated our main models using a combined outcome of readmission or death within 30 days.

Finally, because the results from instrumental variable analyses only apply to the marginal patient—that is, those discharged home with home health care due solely to their closer proximity to a home health agency than to a SNF—we describe the characteristics of these marginal patients. To summarize the characteristics of marginal patients, we follow the method described by Baiocchi et al,[10] dividing the difference in predicted treatment based on the instrument conditional on the value of the covariate by the difference in predicted treatment based on the instrument across all patients. This characterizes the compliers in terms of each observed covariate.

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eTable 1. Summary of Distances to Closest SNF, Closest Home Health Agency, and the Difference Between the Two

	Median	**Interquartile range**
Distance to closest SNF	0	0 to 2.44
Distance to closest HHA	2.14	0 to 6.45
Differential distance (HHA-SNF)	0	0 to 3.6

eTable 2. Summary of Differential Distance Indicator Variable				
			Differential distance in miles (distance to SNF - distance to home health agency)	
	N	**%**	**Median**	**Interquartile range**
Living closer to HHA than to SNF	1,762,614	10.2%	-2.2	-3.5 to -1.3
Living closer to or equidistant to SNF than to HHA	15,473,240	89.8%	0.3	0 to 4.1

eTable 3. First Stage of Instrumental Variable Regression--Relationship Between Discharge to Home Health (vs SNF) and Living Closer to a Home Health Agency Than to a SNF

	All discharges	**Entered hospital 75+ miles from home**	**Entered hospital 150+ miles from home**
Living closer to HHA than to SNF, coefficient	0.014	0.0001	-0.002
F-statistic	263.4	0.004	0.9
N of discharges	17,235,854	748,923	453,838

eTable 4. Characteristics of Study Cohort Stratified by Instrumental Variable

	Living closer to home health agency than to SNF	**Living closer or equidistant to SNF than to home health agency**
	n=1,762,614	n=15,473,240
Age, mean	80.2	80.5
Female, %	61.7	62.3
Race, %		
-White	82.6	86.7
-Black	10.5	9.3
-Hispanic	3.1	1.5
-Asian	2.0	1.1
-Other	1.3	0.9
No. of comorbidities, mean	3.3	3.3
Comorbidities, %		
-Severe Infection	1.2	1.1
-Other Infectious Disease & Pneumonias	20.5	21.0
-Metastatic Cancer/Acute Leukemia	2.9	2.8
-Severe Cancer	4.4	4.4
-Other Cancers	5.2	5.1
-Diabetes Mellitus	31.7	31.3
-Protein-calorie Malnutrition	10.2	9.6
-End-stage Liver Disease	1.4	1.3
-Severe Hematological Disorders	1.3	1.2
-Alcohol Abuse	1.4	1.4
-Psychiatric Comorbidity	17.9	18.2
-Hemiplegia, paraplegia, paralysis, disability	3.5	3.3
-Seizure Disorders	3.3	3.3

-Congestive heart failure	17.6	17.6
-Coronary atherosclerosis or angina	39.9	40.1
-Specified arrhythmias	17.9	18.0
-Chronic obstructive pulmonary disease	22.1	22.8
-Other chronic lung disorders	2.9	2.8
-Dialysis	1.0	0.9
-Decubitus Ulcer or Chronic Skin Ulcer	5.1	5.0
-Septicemia/Shock	5.3	5.3
-Disorders of fluid, electrolyte, acid-base	21.3	21.0
-Iron Deficiency or other anemias	38.5	37.5
-Cardiorespiratory Failure or Shock	8.3	8.4
-Acute Renal Failure	28.8	28.8
-Pancreatic Disease	6.7	6.6
-Rheumatoid Arthritis	4.2	4.3
-Respirator Dependence/Tracheostomy	0.2	0.2
-Transplants	0.4	0.4
-Coagulation Defects/Hematologic Disorders	3.6	3.3
-Hip Fracture/Dislocation	1.9	1.9
5 most common DRGs, %		
-Total knee or hip replacement	12.1	11.8
-Sepsis	5.6	5.7
-Congestive heart failure	5.1	5.3
-Pneumonia	3.6	4.1
-UTI	3.4	3.5
Part A Medicare spending in year prior to admission		
-Any Part A spending, %	35.5	35.7
-Total Part A, mean $	8,118	8,060
ADL function at admission to post-acute care		

-Independent in bathing, %	90.2	90.1
-Independent in dressing, %	96.5	96.0
-Independent in transferring, %	60.9	62.6
-Independent in toileting, %	84.8	84.6
-Independent in eating, %	33.5	32.6
-Complete continence, %	49.0	49.4
-No. of ADLs with independence, mean	4.15	4.15

eTable 5. Twenty Most Common DRGs Discharged to Postacute Care, Grouped by Those With Medical Conditions vs for Surgical/Rehabilitation
Medical DRGs:
871: Septicemia or severe sepsis w/o MV 96+ hours w MCC
690: Kidney & urinary tract infections w/o MCC
291: Heart failure & shock w MCC
292: Heart failure & shock w CC
194: Simple pneumonia & pleurisy w CC
683: Renal failure w CC
193: Simple pneumonia & pleurisy w MCC
641: Misc disorders of nutrition, metabolism, fluids/electrolytes w/o MCC
872: Septicemia or severe sepsis w/o mv 96+ hours w/o MCC
190: Chronic obstructive pulmonary disease w MCC
603: Cellulitis w/o MCC
312: Syncope & collapse
689: Kidney & urinary tract infections w MCC
682: Renal failure w MCC
392: Esophagitis, gastroenteritis & misc digest disorders w/o MCC
191: Chronic obstructive pulmonary disease w CC
Surgical/rehabilitation DRGs:
470: Major joint replacement or reattachment of lower extremity w/o MCC
481: Hip & femur procedures except major joint w CC
65: Intracranial hemorrhage or cerebral infarction w CC or TPA in 24 hrs
552: Medical back problems w/o MCC

eTable 6. Patient Comorbidities Among Patients Discharged to Home Health and to SNF

	to home health	**to SNF**
	n=6,687,339	**n=10,548,515**
	%	**%**
-Severe Infection	1.1	1.2
-Other Infectious Disease & Pneumonias	19.3	21.9
-Metastatic Cancer/Acute Leukemia	3.3	2.4
-Severe Cancer	5.1	3.9
-Other Cancers	5.7	4.7
-Diabetes Mellitus	32.2	30.8
-Protein-calorie Malnutrition	7.3	11.1
-End-stage Liver Disease	1.3	1.3
-Severe Hematological Disorders	1.3	1.2
-Alcohol Abuse	1.1	1.6
-Psychiatric Comorbidity	16.2	19.4
-Hemiplegia, paraplegia, paralysis, disability	2.5	3.8
-Seizure Disorders	2.6	3.8
-Congestive heart failure	17.8	17.9
-Coronary atherosclerosis or angina	41.3	39.4
-Specified arrhythmias	17.6	18.2
-Chronic obstructive pulmonary disease	24.2	21.9
-Other chronic lung disorders	3.2	2.6
-Dialysis	0.9	0.9
-Decubitus Ulcer or Chronic Skin Ulcer	4.0	5.6
-Septicemia/Shock	4.8	5.6
-Disorders of fluid, electrolyte, acid-base	19.4	22.1
-Iron Deficiency or other anemias	35.8	38.7
-Cardiorespiratory Failure or Shock	8.5	8.3
-Acute Renal Failure	28.0	29.3

-Pancreatic Disease	6.6	6.6
-Rheumatoid Arthritis	4.4	4.3
-Respirator Dependence/Tracheostomy	0.2	0.2
-Transplants	0.5	0.3
-Coagulation Defects/Hematologic Disorders	3.4	3.4
-Hip Fracture/Dislocation	1.3	2.3

eTable 7. Instrumental Variable Results Among Subgroups of Patients; Differences in Outcome Between Discharge to Home Health (vs SNF)

	Medical DRGs		**Surgical/rehabilitation DRGs**		**Fee-for-Service**		**Medicare Advantage**		**Urban**		**Hospitals not vertically integrated with PAC**	
	Difference	P-value	Difference	P-value	Difference	P-value	Difference	P-value	Difference	P-value	Difference	P-value
	(se)		(se)		(se)		(se)		(se)		(se)	
Readmission within 30 days	6.5	0.095	14.5	0.223	5.7	0.016	5.3	0.475	6.8	0.005	7.3	0.008
	(3.9)		(11.9)		(2.4)		(7.4)		(2.4)		(2.7)	
Death within 30 days	-4.7	0.045	1.8	0.727	-1.2	0.361	-6.7	0.117	-1.7	0.184	-1.7	0.266
	(2.3)		(5.2)		(1.3)		(4.3)		(1.3)		(1.5)	
Improvement in activities of daily living*	5.1	0.439	-43.7	0.104	0.5	0.911	-6.7	0.605	4.5	0.383	3.6	0.545
	(6.6)		(26.9)		(4.9)		(12.9)		(5.1)		(6.0)	
F-statistic of 1st stage	228.6		14.7		346.7		43.2		266.3		183.1	
Number of observations	4,644,667		2,710,607		13,000,109		4,235,745		13,959,495		10,700,167	

*n=10,315,669 for the outcome of improvement in activities of daily living due to missing assessments at discharge from post-acute care for some patients.

eTable 8. Instrumental Variable Results Among Subgroups of Patients (FFS Discharges Only); Differences in Medicare Payment Amount Between Discharge to Home Health (vs SNF)

	Medical DRGs		**Surgical/rehabilitation DRGs**		**Urban**		**Hospitals not vertically integrated with PAC**	
	Difference	P-value	Difference	P-value	Difference	P-value	Difference	P-value
	(se)		(se)		(se)		(se)	
Medicare payment to hospital	-2	0.997	-326	0.744	-1,712	0.075	-2,266	0.070
	(394)		(998)		(962)		(1248)	
Medicare payment to HHA or SNF	-4,435	<.001	-9,408	0.009	-6,228	<.001	-5234	<.001
	(914)		(3595)		(812)		(888)	
Total Medicare payment in first 60 days after hospital admission	-1,639	0.185	-3,622	0.412	-5,039	<.001	-5,119	0.003
	(1235)		(4414)		(1387)		(1699)	
F-statistic of 1st stage	266.0		16.9		341.9		239.9	
Number of observations	3,583,735		1,977,551		10,259,973		8,081,654	

eTable 9. Instrumental Variable Results for Differences in the Combined End Point of Readmission or Death Within 30 Days of Hospital Discharge for Discharge to Home Health vs SNF

	Instrumental variable regression	
	Difference	P-value
	(95% CI)	
Readmission or death within 30 days of hospital discharge		
All discharges (n=17,235,854)	4.5	0.055
	(0.0 to 9.2)	
Fee-for-service discharges (n= 13,000,109)	4.7	0.045
	(0.1 to 9.2)	
Medicare Advantage discharges (n=4,235,745)	4.0	0.58
	(-10.1 to 18.2)	