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CLINICAL RESEARCH STUDY

Patterns of Readmissions for Three Common Conditions Among Younger US Adults

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ABSTRACT

BACKGROUND: Thirty-day readmissions among elderly Medicare patients are an important hospital quality measure. Although plans for using 30-day readmission measures are under consideration for younger patients, little is known about readmission in younger patients or the relationship between readmissions in younger and elderly patients at the same hospital.

METHODS: By using the 2014 Nationwide Readmissions Database, we examined readmission patterns in younger patients (18-64 years) using hierarchical models to evaluate associations between hospital 30-day, risk-standardized readmission rates in elderly Medicare patients and readmission risk in younger patients with acute myocardial infarction, heart failure, or pneumonia.

RESULTS: There were 87,818, 98,315, and 103,251 admissions in younger patients for acute myocardial infarction, heart failure, and pneumonia, respectively, with overall 30-day unplanned readmission rates of 8.5%, 21.4%, and 13.7%, respectively. Readmission risk in younger patients was significantly associated with hospital 30-day risk-standardized readmission rates for elderly Medicare patients for all 3 conditions. A decrease in an average hospital's 30-day, risk-standardized readmission rates from the 75th percentile to the 25th percentile was associated with reduction in younger patients' risk of readmission from 8.8% to 8.0% (difference: 0.7%; 95% confidence interval, 0.5-0.9) for acute myocardial infarction; 21.8% to 20.0% (difference: 1.8%; 95% confidence interval, 1.4-2.2) for heart failure; and 13.9% to 13.1% (difference: 0.8%; 95% confidence interval, 0.5-1.0) for pneumonia.

CONCLUSIONS: Among younger patients, readmission risk was moderately associated with hospital 30-day, risk-standardized readmission rates in elderly Medicare beneficiaries. Efforts to reduce readmissions among older patients may have important areas of overlap with younger patients, although further research may be necessary to identify specific mechanisms to tailor initiatives to younger patients.

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KEYWORDS: Acute myocardial infarction; Heart failure; Patient readmission; Pneumonia

Hospital readmissions are common,[1-3] expensive,[4,5] and associated with adverse outcomes. Approximately 1 in 5 elderly Medicare beneficiaries are readmitted within 30 days at a cost of more than $17 billion annually,[6] making efforts to reduce readmissions a national priority. The Centers for Medicare & Medicaid Services (CMS) publicly reports hospital 30-day, risk-standardized readmission rates (RSRRs) as a measure of hospital quality.[7] The Patient Protection and Affordable Care Act created the Hospital

Readmissions Reduction Program (HRRP), which financially penalizes hospitals with higher than expected readmission rates.[8,9] Given their associated disease burden and costs,[10-14] 3 common conditions have been the focus of these programs: acute myocardial infarction, heart failure, and pneumonia. Extensive research has attempted to better understand and prevent readmissions in elderly Medicare beneficiaries for these conditions.[15-23]

Although hospital readmissions have been extensively studied in the elderly Medicare population, readmissions are common among nonelderly adult patients. Younger patients are readmitted approximately 2 million times annually, which is similar in number to elderly Medicare beneficiaries.[5] However, overall patterns of and factors associated with hospital readmission in younger patients thus far have been examined using only single state inpatient data.[24-26] Broader knowledge of readmissions among a nationally representative cohort of younger patients with acute myocardial infarction, heart failure, and pneumonia may help tailor specific clinical and policy interventions. This is essential as commercial insurers and Medicaid programs begin to roll out initiatives to reduce readmissions in this population.[27-30] Furthermore, it would be valuable to understand whether younger patients discharged from hospitals with lower readmission rates for elderly Medicare beneficiaries are at lower risk of readmission. If such an association exists, it would suggest that common strategies could be used to reduce readmission rates for both groups.

We used the 2014 Nationwide Readmissions Database (NRD) to evaluate all-cause unplanned readmissions within 30 days in younger patients aged 18 to 64 years after hospitalization for acute myocardial infarction, heart failure, and pneumonia. Our objectives were to determine the timing and causes of readmission for 3 publicly reported conditions for younger patients in the United States and to assess whether the risk of readmission in younger patients is associated with readmission rates among elderly Medicare beneficiaries.

MATERIALS AND METHODS

Data Source

We used data from the Nationwide Readmissions Database (NRD) developed by the Agency for Healthcare Research and Quality's Healthcare Cost and Utilization Project. The NRD contains data on all-payer inpatient stays by compiling information from the Agency for Healthcare Research and

Quality's Healthcare Cost and Utilization Project State Inpatient Databases.[5] The 2014 NRD was constructed from 22 geographically dispersed states. In the unweighted sample, the 2014 NRD represents 51.2% of the US resident population and 49.3% of all US hospitalizations.[31]

Study Population

The unweighted sample was used for all analyses. Our study population included patients who were hospitalized with a primary discharge diagnosis of acute myocardial infarction, heart failure, or pneumonia based on International Classification of Diseases, Ninth Revision, Clinical Modification diagnosis codes (Supplementary Table 1)[32] occurring between January 1, 2014, and November 30, 2014, for younger adult patients (18-64 years). We also examined hospitalizations among elderly (≥65 years) Medicare beneficiaries at the same hospitals to estimate each hospital's disease-specific 30-day RSRRs for Medicare beneficiaries.

Index Admission and Readmissions

Index admissions were defined as the first admission during the study period and all additional admissions occurring more than 30 days after a previous discharge. Admissions for acute myocardial infarction, heart failure, or pneumonia were not considered to be an index admission if patients left against medical advice, were transferred to another acute care hospital, died during the admission, or did not have 30-day follow-up data (eg, admissions in December 2014). Patients transferred in were considered an index admission at the receiving hospital. We also excluded as index admissions those with a missing length of stay, insurance status, and median household income according to ZIP code, and those admitted within 30 days of a prior index admission for the same condition. As per CMS, patients admitted and discharged on the same day with a diagnosis of acute myocardial infarction were not included in the acute myocardial infarction cohort.[32] Patients could contribute multiple index admissions to the analysis so long as the admissions were not within 30 days of a prior index admission for the same condition. Planned readmissions within 30 days of discharge were identified using the CMS Planned Readmission Algorithm.[32] If the first readmission after discharge was planned, then no readmission was attributed to that hospitalization and any subsequent unplanned readmission was not counted as a readmission.[32] We excluded hospitals with fewer than 10 index admissions for elderly Medicare patients or younger patients for

CLINICAL SIGNIFICANCE

- The 30-day readmission rate for younger patients was 8.5% for acute myocardial infarction, 21.4% for heart failure, and 13.7% for pneumonia.

- Readmission risk in younger patients was associated with hospital 30-day, risk-standardized readmission rates among elderly Medicare patients for all 3 conditions.

- Efforts to reduce readmissions among older patients may overlap with younger patients.

each condition to improve the reliability of hospital 30-day RSRRs (Supplementary Figures 1 and 2, available online).

Diagnoses and Timing of Readmission

The reasons for readmission were classified using Agency for Healthcare Research and Quality's single-level Clinical Classification Software applied to the principal International Classification of Diseases, Ninth Revision discharge diagnosis.[33] We identified the percentage of observed 30-day readmissions due to the 5 most common reasons for readmission by single-level Clinical Classification Software categories for the patient cohorts of acute myocardial infarction, heart failure, and pneumonia separately. We reported the percentage of 30-day readmissions occurring on each day (days 1-30) after discharge for each condition.

Sensitivity Analysis

Because individual patients may be counted more than once in the primary analysis, we performed a sensitivity analysis including only the first admission for acute myocardial infarction, heart failure, or pneumonia for each patient.

Statistical Analyses

By using similar procedures to those used by CMS,[32] we estimated hospital-specific, 30-day RSRRs for acute myocardial infarction, heart failure, and pneumonia among elderly Medicare patients using hierarchical logistic regression models with a hospital-specific intercept to account for patient clustering. The binary dependent variable was 30-day, all-cause, unplanned readmission. To account for hospital case mix, we adjusted for patient age, gender, and 29 Elixhauser comorbidities.[34] Separate models were fit for acute myocardial infarction, heart failure, and pneumonia with C-statistics of 0.65, 0.60, and 0.62, respectively. To calculate 30-day RSRRs for each study condition, we used the model to obtain predicted to expected ratios for each hospital. RSRRs were calculated as the product of the predicted to expected ratio and the overall 30-day unplanned readmission rate.

We then evaluated the association between hospital 30-day RSRRs for elderly patients and risk of readmission among younger patients. We fit a hierarchical logistic regression model among younger patients for each condition with a random hospital-specific intercept. The binary dependent variable was 30-day unplanned readmission, and the primary exposure variable was the 30-day RSRR among Medicare beneficiaries at the hospital where the patient was treated. We adjusted for case mix by including patient age, gender, insurance status, length of stay, 29 Elixhauser comorbidities, care received in the emergency department, median household income by ZIP code, and transfer hospitalization. We also adjusted for available hospital characteristics, including hospital ownership status, teaching status, and bed size.

Finally, we sought to understand whether a hospital's 30-day RSRR for a specific condition was associated with the risk of readmission in younger patients with a different condition. For example, we examined whether a hospital's 30-day RSRR for heart failure was associated with the risk of readmission for acute myocardial infarction or pneumonia in younger patients. We hypothesized that the risk of readmission in younger patients for a specific condition would not be significantly associated with readmission rates in elderly Medicare patients for nonidentical conditions. However, if a relationship were to exist, it may suggest that hospital strategies targeting the reduction of readmissions for a specific condition may have broader effects across conditions. First, we identified hospitals with estimates of 30-day RSRRs for all 3 conditions. Next, we fit hierarchical regression models as described but included all three 30-day RSRRs as covariates of interest. The dependent variable was 30-day unplanned readmission among younger patients for the acute myocardial infarction, heart failure, and pneumonia cohorts. A *P* value <.05 was considered statistically significant. All data management and statistical analyses were performed using STATA version 14.2 (StataCorp LP, College Station, Tex).

RESULTS

Baseline Patient, Admission, and Hospital Characteristics

In the 2014 NRD, there were a total of 14.9 million discharges from 2048 hospitals representing 22 geographically dispersed states. There were 87,818, 98,315, and 103,251 index admissions for acute myocardial infarction, heart failure, and pneumonia, respectively, in younger adults (Supplementary Figures 1 and 2, available online). Notably, approximately 25% to 30% of admissions were excluded during construction of the final index admission cohorts for each condition (Supplementary Figure 1, available online). Overall, there were 7504 readmissions for acute myocardial infarction, 21,054 readmissions for heart failure, and 14,165 readmissions for pneumonia. Compared with elderly Medicare beneficiaries, younger patients had lower readmission rates after hospitalization for acute myocardial infarction (8.5% vs 14.9%; *P* < .001) and pneumonia (13.7% vs 16.1%; *P* < .001). However, younger patients had higher rates of readmission after heart failure hospitalizations compared with elderly patients (21.4% vs 20.7%; *P* < .001). Younger patients were more likely to be readmitted if they had a higher number of comorbidities, a longer length of stay, and Medicaid or Medicare (due to disability or end-stage renal disease) (Table 1).

Timing and Causes of Readmission

Among younger patients, the median days from discharge to readmission were 9, 13, and 12 days for acute myocardial infarction, heart failure, and pneumonia, respectively. In general, younger and elderly Medicare patients had similar

Table 1 Baseline Characteristic of Younger Adult Admissions for Three Conditions Stratified by 30-Day Unplanned Readmission

	Acute Myocardial Infarction			Heart Failure			Pneumonia		
	No Readmission	Readmission	ASD	No Readmission	Readmission	ASD	No Readmission	Readmission	ASD
	N = 80,314	N = 7504		N = 77,261	N = 21,054		N = 89,086	N = 14,165	
Admission Characteristics									
Age, y, mean (SD)	54.1 (7.6)	54.8 (7.5)	0.09	53.5 (8.7)	53.5 (9.0)	0.001	49.9 (11.4)	51.6 (10.8)	0.15
Female sex	27.9%	37.4%	0.20	38.3%	39.4%	0.02	52.5%	50.6%	0.04
No. of Elixhauser comorbidities, mean (SD)	2.3 (1.7)	3.4 (1.9)	0.63	3.5 (1.8)	4.1 (1.8)	0.30	3.1 (1.9)	4.0 (2.1)	0.45
No. of Elixhauser comorbidities by categories									
0	12.1%	4.9%	0.63	2.6%	1.5%	0.27	6.4%	2.7%	0.42
1	24.9%	12.0%		9.4%	5.7%		15.2%	7.9%	
2	25.0%	17.9%		17.8%	13.1%		19.9%	13.8%	
3	17.0%	20.0%		21.6%	18.6%		19.8%	18.3%	
≥4	20.6%	45.2%		48.5%	61.1%		38.8%	57.3%	
Median household income by ZIP code									
$1-$39,999	29.6%	35.6%	0.15	40.4%	43.3%	0.07	34.5%	36.7%	0.06
$40,000-$50,999	27.6%	28.1%		26.0%	26.2%		27.9%	28.5%	
$51,000-$65,999	23.4%	20.9%		20.0%	18.5%		21.6%	20.6%	
$66,000+	19.5%	15.4%		13.6%	12.0%		15.9%	14.2%	
Length of stay, d, mean (SD)	4.2 (5.3)	6.5 (7.7)	0.35	5.4 (7.5)	6.3 (8.4)	0.11	4.8 (5.4)	6.1 (7.2)	0.21
Transfer hospitalization	6.8%	9.3%	0.09	2.5%	2.6%	0.01	1.5%	2.2%	0.05
Insurance status									
Medicare (disability/ESRD)	14.7%	30.4%	0.52	30.6%	38.8%	0.30	26.8%	38.9%	0.38
Medicaid	16.9%	25.3%		29.4%	35.1%		24.5%	30.3%	
Private	51.3%	30.8%		26.0%	17.3%		35.2%	23.0%	
Uninsured/other	17.1%	13.5%		13.9%	8.8%		13.5%	7.8%	
Hospital characteristics									
Hospital control									
Government, nonfederal	11.2%	12.6%	0.06	15.0%	15.1%	0.03	14.0%	14.2%	0.02
Private nonprofit	72.1%	69.2%		68.8%	67.7%		68.0%	67.2%	
Private, investor-owned	16.7%	18.3%		16.1%	17.2%		17.9%	18.5%	
Hospital teaching status									
Metropolitan nonteaching	29.2%	29.2%	0.03	28.3%	28.5%	0.01	34.2%	33.9%	0.08
Metropolitan teaching	67.2%	67.7%		66.0%	65.8%		53.9%	56.4%	
Nonmetropolitan hospital	3.6%	3.1%		5.8%	5.8%		11.9%	9.7%	
Hospital bed size									
Small	8.9%	7.6%	0.06	12.1%	11.1%	0.03	17.2%	14.9%	0.07
Medium	26.7%	25.4%		26.7%	26.4%		30.6%	29.8%	
Large	64.5%	67.0%		61.2%	62.5%		52.1%	55.3%	

ASD = absolute standardized differences; ESRD = end-stage renal disease; SD = standard deviation.
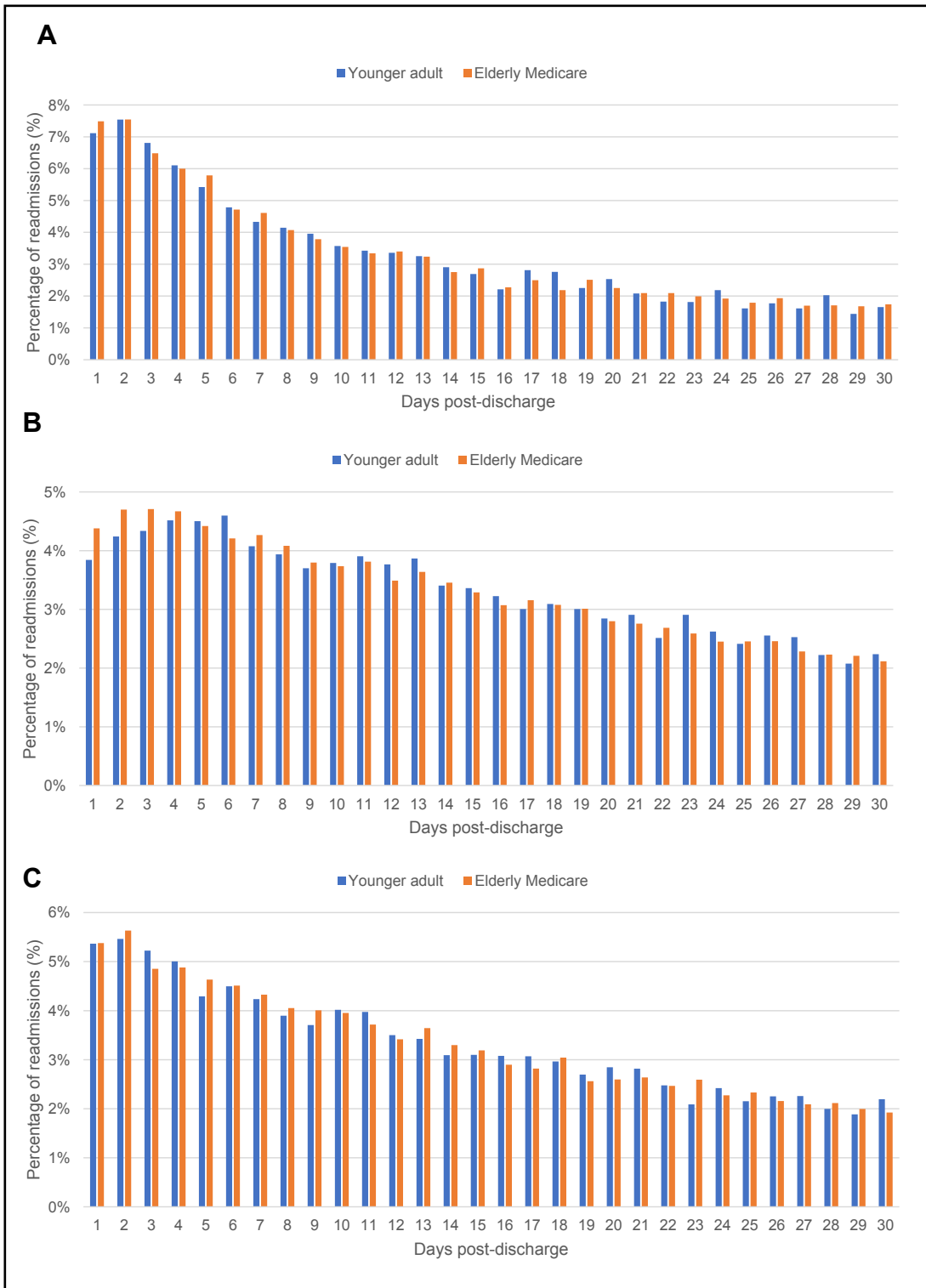
Figure 1   Percentage of readmissions within 30 days of discharge among younger adult and elderly Medicare patients for 3 conditions. The daily percentage of 30-day readmissions after hospitalizations for acute myocardial infarction (**A**), heart failure (**B**), and pneumonia (**C**) among younger adult and elderly Medicare patients.

patterns of readmission timing after discharge (**Figure 1**). Among younger patients, the most common readmission diagnoses were recurrences of each of the respective index

admission diagnoses (**Table 2**). Younger and elderly Medicare patients shared the most common cause of readmission after hospitalizations for heart failure and

Table 2   Common Readmission Diagnoses for Younger Adult and Elderly Medicare Patients

Elderly Medicare Readmissions		Younger Adult Readmissions	
Acute Myocardial Infarction			
1) Congestive heart failure; nonhypertensive	17.9%	1) Acute myocardial infarction	14.4%
2) Acute myocardial infarction	12.0%	2) Congestive heart failure; nonhypertensive	13.0%
3) Septicemia	6.5%	3) Nonspecific chest pain	8.3%
4) Cardiac dysrhythmias	4.2%	4) Complications of surgical procedures or medical care	5.1%
5) Acute and unspecified renal failure	3.7%	5) Complication of device; implant or graft	4.7%
Heart Failure			
1) Congestive heart failure; nonhypertensive	34.0%	1) Congestive heart failure; nonhypertensive	39.9%
2) Septicemia	6.8%	2) Hypertension with complications and secondary hypertension	6.8%
3) Acute and unspecified renal failure	5.6%	3) Acute and unspecified renal failure	4.0%
4) Hypertension with complications and secondary hypertension	4.7%	4) Septicemia	3.9%
5) Respiratory failure; insufficient; arrest	3.9%	5) Respiratory failure; insufficient; arrest	3.7%
Pneumonia			
1) Pneumonia	15.3%	1) Pneumonia	16.4%
2) Septicemia	11.7%	2) Septicemia	9.5%
3) Congestive heart failure; nonhypertensive	9.2%	3) Respiratory failure; insufficient; arrest	6.0%
4) Chronic obstructive pulmonary disease and bronchiectasis	6.0%	4) Chronic obstructive pulmonary disease and bronchiectasis	6.0%
5) Respiratory failure; insufficient; arrest	5.8%	5) Congestive heart failure; nonhypertensive	5.3%

pneumonia, but not for acute myocardial infarction. The most common cause of readmission after a discharge for acute myocardial infarction among elderly Medicare patients was heart failure, whereas it was acute myocardial infarction in younger patients (Table 2). Heart failure was the only diagnosis that appeared as 1 of the top 5 most common causes of readmission after index hospitalizations for acute myocardial infarction, heart failure, and pneumonia among younger and elderly Medicare patients.

Association of Hospital 30-Day, Risk-Standardized Readmission Rates and Readmission Risk in Younger Patients

The median (interquartile range) hospital 30-day RSRRs among elderly Medicare beneficiaries were 14.8% (14.1%-15.6%), 20.7% (19.5%-22.0%), and 16.0% (15.4%-16.7%) for acute myocardial infarction, heart failure, and pneumonia, respectively. A hospital's 30-day RSRR derived

from elderly Medicare patients was significantly associated with the risk of readmission in younger patients for each condition. A 1 percentage point decrease in a hospital's 30-day RSRR for acute myocardial infarction, heart failure, and pneumonia corresponded to an adjusted odds ratio (95% CI) for readmission among younger patients of 0.94 (0.92-0.96; $P < .001$), 0.96 (0.95-0.96; $P < .001$), and 0.95 (0.93-0.97; $P < .001$), respectively. In other words, a decrease in an average hospital's 30-day RSRR from the 75th percentile to the 25th percentile was associated with a reduction in a younger patient's risk of readmission from 8.8% to 8.0% (difference: 0.7%; 95% CI, 0.5-0.9; $P < .001$) for acute myocardial infarction; 21.8% to 20.0% (difference: 1.8%; 95% CI, 1.4-2.2; $P < .001$) for heart failure; and 13.9% to 13.1% (difference: 0.8%; 95% CI 0.5-1.0; $P < .001$) for pneumonia. The average marginal effect of an average hospital's 30-day RSRR on the risk of readmission in younger patients for each condition is demonstrated in Figure 2.
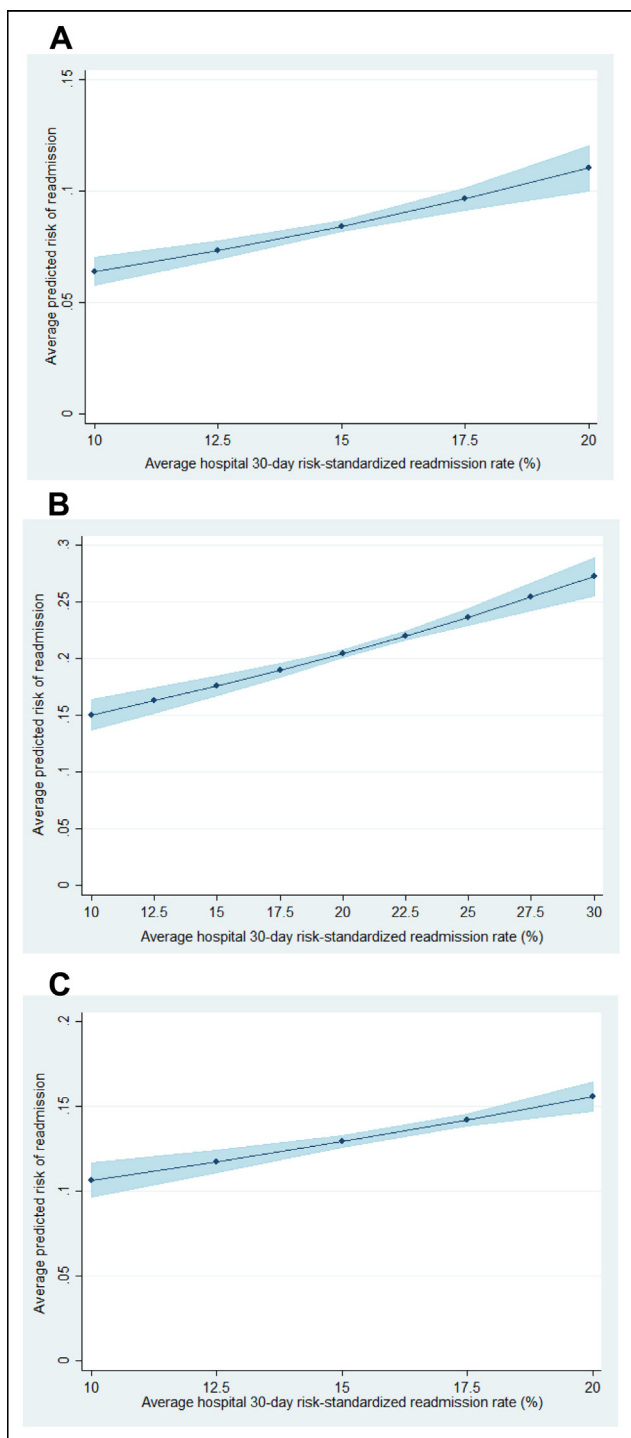
Figure 2 Predicted risk of readmission for younger adult patients across a spectrum of hospital 30-day RSRRs among elderly Medicare beneficiaries. Average predicted risks of readmission (*solid line*) and 95% CIs (*shaded area*) for younger adult patients admitted for acute myocardial infarction (**A**), heart failure (**B**), or pneumonia (**C**) at varying levels of an average hospital's 30-day RSRR derived from elderly Medicare patients hospitalized for each respective condition.

Thirty-day RSRRs were available for all 3 conditions at 815 hospitals. Among this subgroup, we examined the association of 30-day RSRRs for all 3 conditions on the risk of readmission for hospitalizations of younger patients in the acute myocardial infarction, heart failure, and pneumonia cohorts (Table 3). A hospital's 30-day RSRR for heart failure was significantly associated with the risk of readmission in younger patients across all 3 conditions, whereas 30-day RSRRs for acute myocardial infarction were significantly associated with the risk of readmission for acute myocardial infarction and heart failure but not pneumonia. A hospital's 30-day RSRR for pneumonia was significantly associated with the risk of readmission in younger patients for pneumonia only, not acute myocardial infarction or heart failure (Table 3).

In a sensitivity analysis including only the first hospitalization for acute myocardial infarction, heart failure, or pneumonia per patient, we discovered a similar association between a hospital's RSRR in the elderly and the risk of readmission in the nonelderly as was seen in the primary analysis (Supplementary Tables 2 and 3, available online).

DISCUSSION

Our study has 2 important findings. First, hospital-level 30-day RSRRs among elderly Medicare beneficiaries were significantly associated with the risk of readmission among younger adults for all 3 conditions. On the basis of our findings, a reduction in an average hospital's RSRR from the 75th percentile to the 25th percentile was associated with an absolute readmission risk reduction ranging from 0.7% to 1.8% in younger patients depending on the condition, suggesting a moderate overall association. Second, we found an unexpected association between the 30-day RSRRs in elderly Medicare beneficiaries and the risk of readmission in younger patients across conditions. A hospital's 30-day RSRR for heart failure was significantly associated with the risk of readmission for all 3 conditions, whereas that for acute myocardial infarction was related to acute myocardial infarction and heart failure but not pneumonia. However, there was no significant relationship between a hospital's RSRR for older adults with pneumonia and the risk of readmission for younger adults with acute myocardial infarction or heart failure. Taken together, these findings suggest efforts to reduce readmissions among older patients may have important areas of overlap with younger patients, although further research is necessary to identify specific mechanisms that explain this relationship.

Earlier work examining characteristics and readmission patterns among younger adult patients has been limited.[5,24] Prior studies have used California inpatient administrative claims data between 2007 and 2009 to evaluate readmissions among patients aged 18 to 64 years.[24-26] In one study, the overall readmission rates after index hospitalization for acute myocardial infarction, heart failure, and

Table 3 Adjusted Odds Ratios of 30-Day, Risk-Standardized Readmission Rates for All Three Conditions on the Probability of Readmission in Younger Patients for Acute Myocardial Infarction, Heart Failure, and Pneumonia

	Adjusted OR (95% CI)		
Exposure	AMI Younger Cohort N = 86,779 N/N = 815/840 Available Hospitals	CHF Younger Cohort N = 84,488 n/N = 815/1241 Available Hospitals	PNA Younger Cohort N = 78,390 n/N = 815/1550 Available Hospitals
30-d AMI RSRR for Medicare patients	0.96 (0.94-0.98)*	0.97 (0.95-0.98)†	0.99 (0.97-1.01)
30-d HF RSRR for Medicare patients	0.97 (0.96-0.98)†	0.97 (0.96-0.98)†	0.97 (0.96-0.99)†
30-d PNA RSRR for Medicare patients	0.98 (0.96-1.00)	0.99 (0.97-1.01)	0.96 (0.94-0.98)†

Adjusted ORs (95% CI) correspond to a 1 percentage point decrease in a hospital's 30-day RSRR. There were 815 hospitals with estimates of 30-day, risk-standardized readmissions for all 3 conditions. The number of hospitals with estimated RSRRs varied by condition and are shown at the top of each column. The total number of younger patients in each cohort is included at the top of each column.

AMI = acute myocardial infarction; CI = confidence interval; CHF = congestive heart failure; OR = odds ratio; PNA = pneumonia; RSRR = risk-standardized readmission rate.

*$P < .01$.

†$P < .001$.

pneumonia were 11.2%, 23.4%, and 14.4%, respectively, in their cohort of younger adult patients.[24] Each of these was greater than the overall readmission rates of 8.5%, 21.4%, and 13.7% readmission rates for acute myocardial infarction, heart failure, and pneumonia, respectively, reported in our study. This lower rate of readmissions might be explained by the inclusion of a larger, more nationally representative cohort of patients in our study along with continued declines in readmission rates for acute myocardial infarction and heart failure.[35] The modestly higher rate of readmission after heart failure hospitalizations among younger patients compared with elderly patients deserves brief mention (21.4% vs 20.7%). Although this finding has been demonstrated for heart failure,[24] the mechanism explaining this phenomenon remains unclear. We speculate on 2 potential mechanisms. First, perhaps differences in the common causes of heart failure between younger and older patients partially account for this phenomenon. For instance, heart failure with reduced ejection fraction is a more common cause of heart failure among younger patients and may be associated with a worse prognosis in this age group.[13] Second, socioeconomic factors, including lack of health insurance, may pose challenges to appropriate outpatient follow-up and management for younger patients.

Our study is the first to examine the association between readmissions for elderly and younger patients after the HRRP was introduced. We extend prior literature by introducing the novel finding that 30-day RSRRs for elderly Medicare beneficiaries have a significant association with the risk of readmission for younger patients for acute myocardial infarction, heart failure, and pneumonia. This finding has several important implications. First, because other insurers beyond Medicare are concerned with reducing

readmissions, understanding the mechanisms by which hospitals with low 30-day RSRRs achieve reduced readmissions across the spectrum of age is an important step in designing and implementing readmission reduction programs more broadly. One possible mechanism may include similar patterns and timing of readmission.[24,36] Second, there may be substantial costs associated with reducing a hospital's RSRR in elderly patients.[37] On the basis of our findings, a reduction in a hospital's RSRR by 1 percentage point is associated with an approximately 5% reduction in the relative probability of readmission and a smaller reduction in the absolute risk among younger patients across all 3 conditions. Thus, an increased understanding of the factors associated with readmissions in nonelderly patients may inform the development of more cost-effective strategies to reduce readmissions in this population.

We also demonstrate that hospital 30-day RSRRs may be associated with risk of readmission across conditions. For instance, we found that a hospital's 30-day RSRR for heart failure was significantly associated with readmission in the younger population across all 3 conditions, suggesting that this measure may be a good indicator of overall quality of care. Indeed, heart failure was the only diagnosis in the top 5 causes of readmission for all 3 conditions in both younger and elderly Medicare patients. Therefore, hospitals that effectively manage heart failure among elderly Medicare beneficiaries may do so by proactively preventing readmissions for heart failure across ages and conditions using diverse approaches with broad applicability.

There are some data to support this speculation. A prior study reported several hospital strategies that were associated with reduced hospital RSRRs for heart failure.[38] These included hospital partnerships with community physicians

and local hospitals aimed at reducing readmissions; discharge summaries sent directly to the patient's primary care physician; arrangement of follow-up appointments before discharge; and staff assigned to follow-up specific test results.[38] These broad strategies may, in part, reduce readmissions across ages and conditions, thus explaining the observed association between a hospital's RSRR for heart failure and the risk of readmission among younger patients with acute myocardial infarction or pneumonia. Nevertheless, given the relatively small sample size of this subgroup, these findings should be considered hypothesis-generating and warrant further evaluation.

Our findings have several important implications. There is growing momentum for initiatives aimed at mitigating healthcare costs by reducing readmissions. The HRRP has imposed substantial financial penalties, resulting in approximately $1 billion in penalties since the program's inception in October 2012.[9] Although not without controversy, many studies have demonstrated multiple beneficial effects of this policy.[39-41] Inspired by the initial success of the HRRP, Medicaid and private insurers also are designing programs to reduce readmissions for their nonelderly enrollees.[27-30] For example, Illinois has implemented a Medicaid Readmission Penalty Program based on the SMART Act.[42] It remains to be determined whether best practices and quality-improvement efforts targeting older adults, such as Project Better Outcomes for Older Adults through Safe Transitions (BOOST)[43] and Project Re-Engineered Discharge (RED),[44-46] will be similarly effective in younger adult patients.

Study Limitations

Our study should be interpreted in the context of the following study design issues. First, because of data limitations in the NRD, we were unable to account for complete measures of clinical and socioeconomic risk in our models.[47-49] Thus, residual confounding due to both elderly and younger patients being sicker at some hospitals remains an important concern as with most observational studies. Second, we were unable to use the specific case-mix adjustment method used by CMS for estimation of 30-day RSRRs for HRRP and Hospital Compare.[32] This method of risk-adjustment requires 12 months of claims data before admission, which was not available in this dataset. However, as in prior work, we used Elixhauser comorbidities for case-mix adjustment[50]; the discrimination of our models compared similarly to models used by CMS.[21-23] Third, we did not have data available on vital status among patients who were not readmitted. Therefore, we were unable to account for the competing risk of death after discharge. However, most operational initiatives for programs targeted toward readmission consider mortality and readmission as separate outcomes. Fourth, there are important limitations of the NRD that deserve specific mention. The NRD includes only hospitalizations from community hospitals as defined by the American Hospital Association; therefore,

admissions to federal hospitals such as the Veterans Affairs health systems are not included. Readmissions to hospitals in different states from the index hospitalization are not captured because the NRD is a compilation of various State Inpatient Databases. Also, readmissions when the discharge date occurred in 2015 were not captured. These limitations of the dataset may have led to a modest underestimation of the actual number of readmissions that occurred. Finally, we also recognize the limitations regarding our 30-day RSRR calculations due to the availability of 11 months of data in the NRD compared with the 3 years of historical data used in the CMS measures. This leads to the potential of measurement error in our 30-day RSRR calculations. Although there is no method to compare the hospital-specific RSRRs we estimated with Hospital Compare because of the de-identified nature of the NRD, our national observed readmission rates were largely comparable. Specifically, our 30-day observed readmission rates for elderly Medicare beneficiaries for acute myocardial infarction, congestive heart failure, and pneumonia were 14.9%, 20.7%, and 16.1%, respectively, whereas currently on Hospital Compare they are 16.8%, 21.9%, and 17.1%, respectively.[51] Overall, our calculated rates were modestly lower than the reported readmission rates on Hospital Compare that we suspect are due to the inclusion of generally healthier Medicare Advantage patients.

CONCLUSIONS

Approximately 1 in 12 patients with acute myocardial infarction, 1 in 5 patients with heart failure, and 1 in 7 patients with pneumonia aged less than 65 years are readmitted within 30 days of discharge. Their risk of readmission is moderately associated with a hospital's rate of 30-day readmissions among elderly Medicare beneficiaries. Further research is needed to elucidate the mechanisms responsible for 30-day readmissions among younger patients and whether it is most effective to improve existing readmission reduction programs or design novel strategies targeted to younger adults.

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SUPPLEMENTARY DATA

Supplementary tables and figures accompanying this article can be found in the online version at http://dx.doi.org/10. 1016/j.amjmed.2017.05.025.

Supplementary Table 1   International Classification of Diseases, Ninth Revision, Clinical Modification Inclusion Criteria for Acute Myocardial Infarction, Heart Failure, and Pneumonia Index Admissions

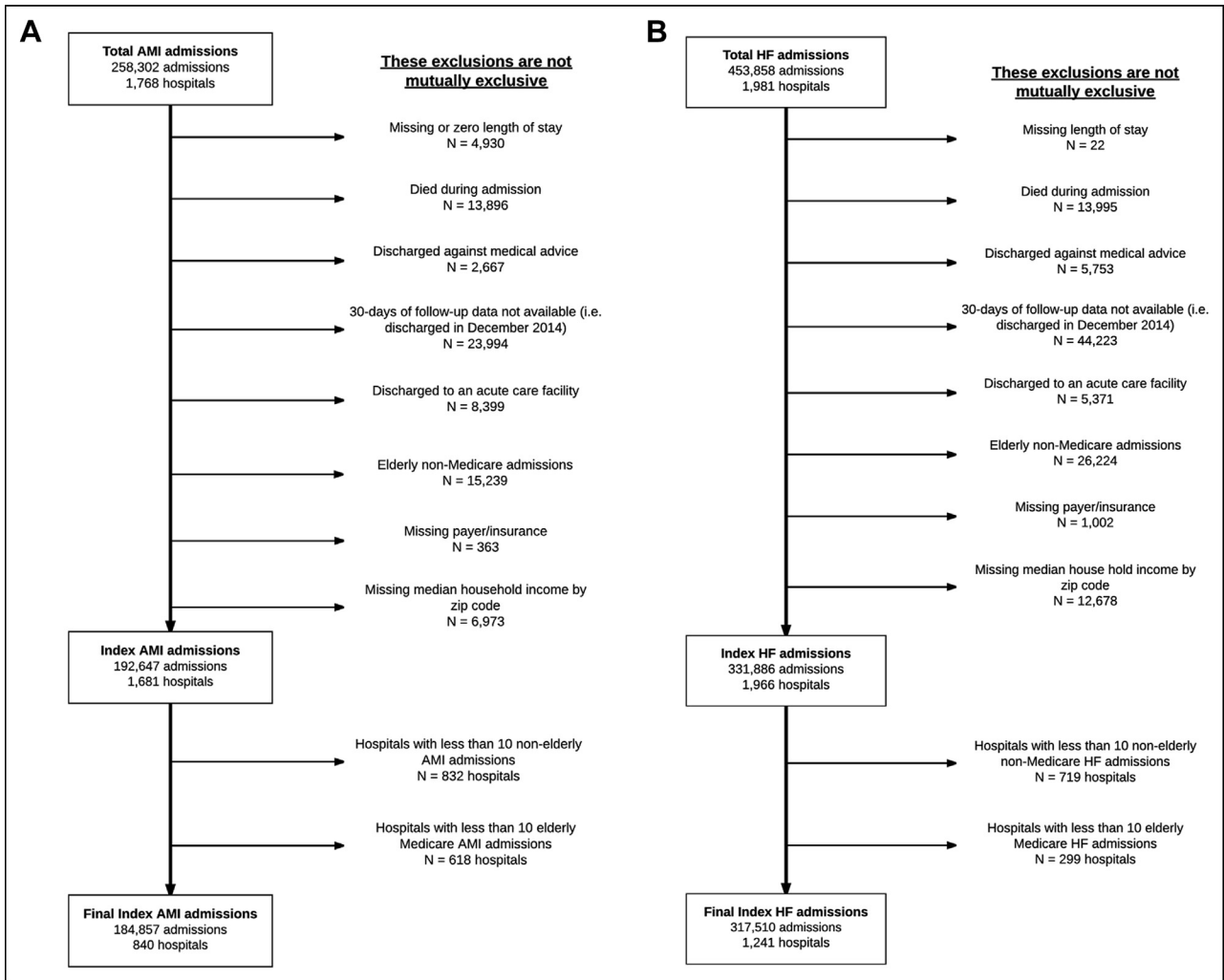| ICD-9-CM Codes	Description
AMI	
410.00	AMI (anterolateral wall) episode of care unspecified
410.01	AMI (anterolateral wall) initial episode of care
410.10	AMI (other anterior wall) episode of care unspecified
410.11	AMI (other anterior wall) initial episode of care
410.20	AMI (inferolateral wall) episode of care unspecified
410.21	AMI (inferolateral wall) initial episode of care
410.30	AMI (inferoposterior wall) episode of care unspecified
410.31	AMI (inferoposterior wall) initial episode of care
410.40	AMI (other inferior wall) episode of care unspecified
410.41	AMI (other inferior wall) initial episode of care
410.50	AMI (other lateral wall) episode of care unspecified
410.51	AMI (other lateral wall) initial episode of care
410.60	AMI (true posterior wall) episode of care unspecified
410.61	AMI (true posterior wall) initial episode of care
410.70	AMI (subendocardial) episode of care unspecified
410.71	AMI (subendocardial) initial episode of care
410.80	AMI (other specified site) episode of care unspecified
410.81	AMI (other specified site) initial episode of care
410.90	AMI (unspecified site) episode of care unspecified
410.91	AMI (unspecified site) initial episode of care
CHF	
402.01	Malignant hypertensive heart disease with CHF
402.11	Benign hypertensive heart disease with CHF
402.91	Hypertensive heart disease with CHF
404.01	Malignant hypertensive heart and renal disease with CHF
404.03	Malignant hypertensive heart and renal disease with CHF and renal failure
404.11	Benign hypertensive heart disease and renal disease with CHF
404.13	Benign hypertensive heart disease and renal disease with CHF and renal failure
404.91	Unspecified hypertensive heart and renal disease with CHF
404.93	Hypertension and nonspecified heart and renal disease with CHF and renal failure
428.0	Congestive heart failure, unspecified
428.1	Left heart failure
428.2	Systolic heart failure, unspecified
428.21	Systolic heart failure, acute
428.22	Systolic heart failure, chronic
428.23	Systolic heart failure, acute or chronic
428.3	Diastolic heart failure, unspecified
428.31	Diastolic heart failure, acute
428.32	Diastolic heart failure, chronic

Supplementary Table 1   Continued

ICD-9-CM Codes	Description
428.33	Diastolic heart failure, acute or chronic
428.4	Combined systolic and diastolic heart failure, unspecified
428.41	Combined systolic and diastolic heart failure, acute
428.42	Combined systolic and diastolic heart failure, chronic
428.43	Combined systolic and diastolic heart failure, acute or chronic
428.9	Heart failure, unspecified
Pneumonia	
480.0	Pneumonia due to adenovirus
480.1	Pneumonia due to respiratory syncytial virus
480.2	Pneumonia due to parainfluenza virus
480.3	Pneumonia due to SARS-associated coronavirus
480.8	Viral pneumonia: pneumonia due to other virus not elsewhere classified
480.9	Viral pneumonia unspecified
481.0	Pneumococcal pneumonia (streptococcus pneumoniae pneumonia)
482.0	Pneumonia due to *Klebsiella pneumoniae*
482.1	Pneumonia due to Pseudomonas
482.2	Pneumonia due to *Haemophilus influenzae*
482.3	Pneumonia due to streptococcus unspecified
482.31	Pneumonia due to streptococcus group A
482.32	Pneumonia due to streptococcus group B
482.39	Pneumonia due to other streptococcus
482.4	Pneumonia due to staphylococcus unspecified
482.41	Pneumonia due to *Staphylococcus aureus*
482.42	Methicillin resistant pneumonia due to *Staphylococcus aureus*
482.49	Other staphylococcus pneumonia
482.81	Pneumonia due to anaerobes
482.82	Pneumonia due to *Escherichia coli*
482.83	Pneumonia due to other gram-negative bacteria
482.84	Pneumonia due to Legionnaires' disease
482.89	Pneumonia due to other specified bacteria
482.9	Bacterial pneumonia unspecified
483.0	Pneumonia due to *Mycoplasma pneumoniae*
483.1	Pneumonia due to chlamydia
483.8	Pneumonia due to other specified organism
485.0	Bronchopneumonia organism unspecified
486.0	Pneumonia organism unspecified
487.0	Influenza with pneumonia
488.11	Influenza due to identified novel H1N1 influenza virus with pneumonia

ICD-9-CM codes obtained from the 2014 Measures Updates and Specifications Report Hospital-Level 30-Day Risk-Standardized Readmission Measures.[32]

AMI = acute myocardial infarction; CHF = congestive heart failure; ICD-9-CM = International Classification of Diseases, Ninth Revision, Clinical Modification; SARS = severe acute respiratory syndrome.
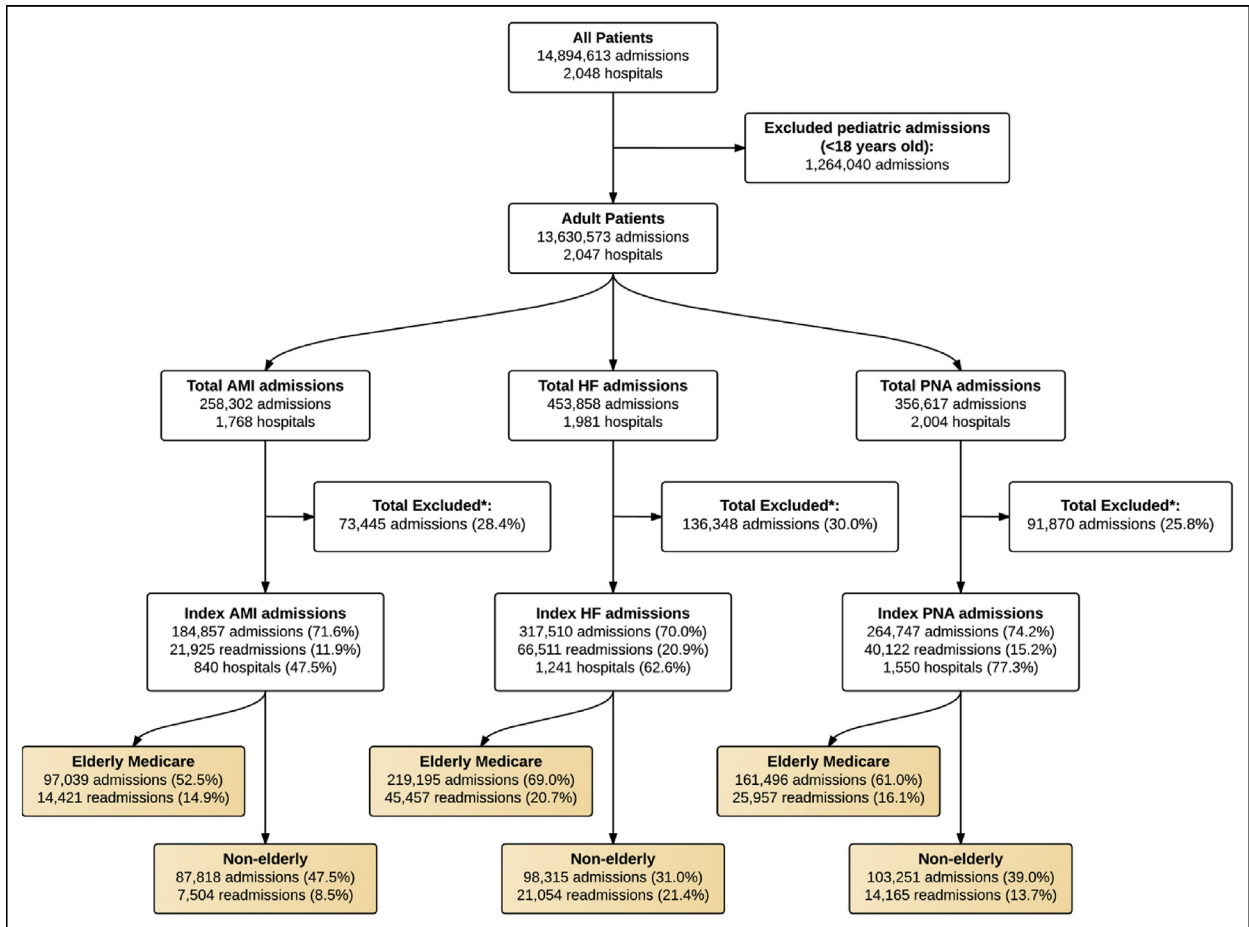
Supplementary Figure 1 Flow diagram of study sample. *Detailed exclusions are shown in Supplementary Figure 2. AMI = acute myocardial infarction; HF = heart failure; PNA = pneumonia.

A

Total AMI admissions
258,302 admissions
1,768 hospitals

These exclusions are not mutually exclusive

Missing or zero length of stay
N = 4,930

Died during admission
N = 13,896

Discharged against medical advice
N = 2,667

30-days of follow-up data not available (i.e. discharged in December 2014)
N = 23,994

Discharged to an acute care facility
N = 8,399

Elderly non-Medicare admissions
N = 15,239

Missing payer/insurance
N = 363

Missing median household income by zip code
N = 6,973

Index AMI admissions
192,647 admissions
1,681 hospitals

Hospitals with less than 10 non-elderly AMI admissions
N = 832 hospitals

Hospitals with less than 10 elderly Medicare AMI admissions
N = 618 hospitals

Final Index AMI admissions
184,857 admissions
840 hospitals

B

Total HF admissions
453,858 admissions
1,981 hospitals

These exclusions are not mutually exclusive

Missing length of stay
N = 22

Died during admission
N = 13,995

Discharged against medical advice
N = 5,753

30-days of follow-up data not available (i.e. discharged in December 2014)
N = 44,223

Discharged to an acute care facility
N = 5,371

Elderly non-Medicare admissions
N = 26,224

Missing payer/insurance
N = 1,002

Missing median house hold income by zip code
N = 12,678

Index HF admissions
331,886 admissions
1,966 hospitals

Hospitals with less than 10 non-elderly non-Medicare HF admissions
N = 719 hospitals

Hospitals with less than 10 elderly Medicare HF admissions
N = 299 hospitals

Final Index HF admissions
317,510 admissions
1,241 hospitals

Supplementary Figure 2   Flow diagram of admission- and hospital-level exclusions for acute myocardial infarction, heart failure, and pneumonia. **A**, Acute myocardial infarction. **B**, Heart failure. **C**, Pneumonia.

C

Total PNA admissions
356,617 admissions
2,004 hospitals

These exclusions are not
mutually exclusive

Missing length of stay
N = 18

Died during admission
N = 12,069

Discharged against medical advice
N = 4,581

30-days of follow-up data not available (i.e.
discharged in December 2014)
N = 38,092

Discharged to an acute care facility
N = 3,423

Elderly non-Medicare admissions
N = 18,697

Missing payer/insurance
N = 1,111

Missing median household income by
zip code
N = 11,271

Index PNA admissions
273,660 admissions
2,000 hospitals

Hospitals with less than 10 non-elderly
non-Medicare PNA admissions
N = 413 hospitals

Hospitals with less than 10 elderly
Medicare PNA admissions
N = 194 hospitals

Final Index PNA admissions
264,747 admissions
1,550 hospitals

Supplementary Figure 2 (*Continued*).

Supplementary Table 2   Description of Sensitivity Analysis Cohort

	AMI	Heart Failure	Pneumonia
Elderly Medicare index admissions	90,990	173,832	148,570
Readmissions (%)	12,856 (14.1)	33,160 (19.1)	22,639 (15.2)
Nonelderly index admissions	84,489	74,781	97,035
Readmissions (%)	6663 (7.9)	13,430 (18.0)	12,347 (12.7)

AMI = acute myocardial infarction.

Supplementary Table 3   Adjusted Odds Ratios for Readmission Among Younger Patients for a 1 Percentage Point Decrease in a Hospital's 30-Day, Risk-Standardized Readmission Rates for Each Condition in the Primary and Sensitivity Analyses

	Adjusted OR	95% CI	P Value
Acute myocardial infarction			
Primary analysis	0.94	0.92-0.96	<.001
Sensitivity analysis	0.93	0.91-0.95	<.001
Heart failure			
Primary analysis	0.96	0.95-0.96	<.001
Sensitivity analysis	0.94	0.93-0.96	<.001
Pneumonia			
Primary analysis	0.95	0.93-0.97	<.001
Sensitivity analysis	0.94	0.92-0.96	<.001

CI = confidence interval; OR = odds ratio.