

RESEARCH

Hospital readmission performance and patterns of readmission: retrospective cohort study of Medicare admissions

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Abstract

Objectives To determine whether high performing hospitals with low 30 day risk standardized readmission rates have a lower proportion of readmissions from specific diagnoses and time periods after admission or instead have a similar distribution of readmission diagnoses and timing to lower performing institutions.

Design Retrospective cohort study.

Setting Medicare beneficiaries in the United States.

Participants Patients aged 65 and older who were readmitted within 30 days after hospital admission for heart failure, acute myocardial infarction, or pneumonia in 2007-09.

Main outcome measures Readmission diagnoses were classified with a modified version of the Centers for Medicare and Medicaid Services' condition categories, and readmission timing was classified by day (0-30) after hospital discharge. Hospital 30 day risk standardized readmission rates over the three years of study were calculated with public reporting methods of the US federal government, and hospitals were categorized with bootstrap analysis as having high, average, or low readmission performance for each index condition. High and low performing hospitals had $\geq 95\%$ probability of having an interval estimate respectively less than or greater than the national 30 day readmission rate over the three

year period of study. All remaining hospitals were considered average performers.

Results For readmissions in the 30 days after the index admission, there were 320 003 after 1 291 211 admissions for heart failure (4041 hospitals), 102 536 after 517 827 admissions for acute myocardial infarction (2378 hospitals), and 208 438 after 1 135 932 admissions for pneumonia (4283 hospitals). The distribution of readmissions by diagnosis was similar across categories of hospital performance for all three conditions. High performing hospitals had fewer readmissions for all common diagnoses. Median time to readmission was similar by hospital performance for heart failure and acute myocardial infarction, though was 1.4 days longer among high versus low performing hospitals for pneumonia ($P < 0.001$). Findings were unchanged after adjustment for other hospital characteristics potentially associated with readmission patterns.

Conclusions High performing hospitals have proportionately fewer 30 day readmissions without differences in readmission diagnoses and timing, suggesting the possible benefit of strategies that lower risk of readmission globally rather than for specific diagnoses or time periods after hospital stay.

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Appendix 1: Supplementary tables

Appendix 2: Supplementary figures

Introduction

Rates of readmission in the 30 days after an index admissions for heart failure, acute myocardial infarction, or pneumonia remain high and variable across hospitals in the United States.¹⁻³ In 2007-09, publicly reported 30 day rates of readmission standardized for risk ranged from 17% to 33% for patients admitted with heart failure, 15% to 27% for patients admitted with acute myocardial infarction, and 14% to 26% for patients admitted with pneumonia.⁴⁻⁵

Little is known about the relation between hospital rates of readmission and the diagnoses and timing of readmissions. For example, do high performing hospitals with the lowest 30 day readmission rates have fewer readmissions due to the same conditions that prompted the initial admission or that occur soon after discharge? If so, readmissions for recurrent illnesses should be less common and the median time to readmission longer at these institutions. In contrast, do high performing hospitals have broadly reduced risk of readmission for the spectrum of conditions necessitating readmission and is this risk of readmission lower for the entire month after discharge? In this case, both the distribution of readmission diagnoses and the median time to readmission should be similar to those of lower performing hospitals even though the absolute number of readmissions is less. Given uncertainties about which strategies are most effective in reducing readmissions in the context of contemporary practice, answers to these questions might illuminate how readmissions have been empirically reduced at hospitals with the lowest rates.

As previous qualitative research has found that hospitals with the lowest 30 day mortality for acute myocardial infarction possess organizational capacities with diffuse salutary impact beyond disease specific processes and protocols,⁶⁻⁷ we hypothesized that high performing hospitals with the lowest 30 day readmission rates would have proportionately fewer readmissions across all diagnoses and time periods after discharge. To test this, we studied a national cohort of beneficiaries of Medicare fee for service health insurance who were readmitted within 30 days after admission for heart failure, acute myocardial infarction, or pneumonia in 2007-09. We examined whether the spectrum of readmission diagnoses and median time to readmission varied by categorization of performance and, if so, whether they varied for better and worse performers in a consistent manner for all three conditions. We focused on patients who were initially admitted for heart failure, acute myocardial infarction, or pneumonia as these illnesses are among the most common causes of admission in older people⁸ and are the focus of performance based reimbursement by the Centers for Medicare and Medicaid Services.⁴⁻⁹

Methods

Data sources and study population

We used Medicare standard analytic and denominator files to identify index admissions to acute care hospitals in 2007-09 with a principal discharge diagnosis of heart failure, acute myocardial infarction, or pneumonia. Cohorts were defined with ICD-9 (international classification of diseases, 9th revision, clinical modification) codes used in readmission measures publically reported by the Centers for Medicare and Medicaid Services (table A in appendix 1).¹⁰⁻¹² We included patients aged 65 and older with a complete claims history for one year before admission. Reasons for exclusion included death in hospital, less than 30 days after discharge with enrollment in Medicare fee for service, transfer to another acute care facility, and

discharge against medical advice.¹⁰⁻¹² To provide more reliable estimates of hospital performance, we did not include patients from hospitals with fewer than 25 index admissions for each condition or no readmissions over the study period. We required that hospitals be represented in 2008 American Hospital Association survey data.

We then used definitions consistent with current Centers for Medicare and Medicaid Services measures (table B in appendix 1) to identify all qualifying readmissions for any cause to any short term acute care hospital within 30 days of the index admission.¹⁰⁻¹² We specifically excluded planned readmissions for revascularization procedures after admission for acute myocardial infarction. As with the Centers for Medicare and Medicaid Services measures, only the first readmission within 30 days of discharge was considered as a 30 day readmission. Additional readmissions within this 30 day period were not counted as 30 day readmissions or index admissions for the same condition. Subsequent admissions occurring after 30 days from discharge were counted as index admissions if they met inclusion criteria. All study analyses were performed on these readmission cohorts.

Categorization of readmission diagnoses and timing

To characterize readmission patterns across hospitals, we classified individual diagnoses for readmitted patients using a modified version of the Centers for Medicare and Medicaid Services condition categories, as previously described.¹³⁻¹⁴ Each of the 189 condition categories is structured around a reasonably well specified disease or medical condition.¹³ Because nearly 90% of the 189 condition categories each accounted for less than 1% of all readmissions, however, we consolidated related diagnoses in a shorter list of 30 modified condition categories to make data presentation more clinically meaningful (table C in appendix 1). Based on our opinion, these 30 modified condition categories were designed to be clinically internally consistent and capture the most common diagnostic categories associated with readmission. Cardiopulmonary diagnoses were subdivided into a larger number of diagnostic categories given their expected importance after index admission for heart failure, acute myocardial infarction, or pneumonia.

We classified timing of readmission by day (0-30) after hospital discharge.

Hospital performance

For each hospital, we calculated separate 30 day readmission rates standardized for risk after index admission for heart failure, acute myocardial infarction, and pneumonia. The National Quality Forum¹⁵ approved these measures and an independent committee of statisticians nominated by the Committee of Presidents of the Statistical Societies endorsed the validity of the methods.¹⁶ Risk standardized readmission rates are publically reported by the Centers for Medicare and Medicaid Services⁴⁻⁹ and have been incorporated into incentive programs within the Affordable Care Act.⁹ The modeling strategy used for risk standardization accounts for correlation of observed readmission rates within a hospital and reflects the assumption that, after adjustment for sampling variability and patient characteristics including age, sex, and comorbidities, the remaining variation in readmission rates reflects hospital quality.¹⁰⁻¹²

To compare readmission diagnoses and timing across hospitals of different performance levels, we used the bootstrap algorithm to construct a 95% interval estimate for each 30 day risk standardized readmission rate and divided hospitals into high,

average, and low performers for each index condition.¹⁰⁻¹² High and low performing hospitals had a 95% or greater probability of having an interval estimate respectively less than or greater than the national rate over the three year period of study. All remaining hospitals were considered average. For each hospital, we calculated performance separately for heart failure, acute myocardial infarction, and pneumonia cohorts.

Outcomes

Readmission diagnoses by hospital performance

We identified the percentage of readmissions for each of the 10 most common diagnostic categories by modified condition categories among hospitals with high, average, and low performance and compared these percentages across hospital performance groups.

To deal with potential confounding of results by differences in hospital characteristics among performance groups we also examined whether hospital 30 day risk standardized readmission rates were associated with the percentage of readmissions for each of the 10 most common diagnostic categories by modified condition category after adjustment for hospital factors used in performance reports by the Centers for Medicare and Medicaid Services⁴ and previous studies examining hospital readmissions.¹⁷⁻¹⁹

Readmission timing by hospital performance

We calculated the median time to readmission among hospitals with high, average, and low performance and compared this timing across performance categories.

To deal with potential confounding, we also examined whether hospital 30 day risk standardized readmission rates were associated with median time to readmission after adjustment for the additional hospital factors cited above.

Statistical analyses

Readmission diagnoses by hospital performance

We first identified the percentage of observed 30 day readmissions for the 30 most common readmission diagnostic categories by modified condition category for each hospital in the heart failure, acute myocardial infarction, and pneumonia cohorts. We also noted each hospital's percentage of observed 30 day readmissions for cardiovascular diagnoses after admissions for heart failure and acute myocardial infarction, and pulmonary diagnoses after admissions for pneumonia. The modified condition category groups comprising cardiovascular and pulmonary diseases are listed in tables D and E in appendix 1.

We then calculated a weighted average of the percentage of hospitals' readmissions for the 10 most common readmission diagnoses by modified condition category for high, average, and low performing hospitals. Weighting was proportionate to the number of readmissions for each hospital during 2007-09. We calculated summary statistics for each hospital performance level.

To examine the association between hospital performance and readmission diagnoses across the range of hospital 30 day risk standardized readmission rates, we developed weighted regression models of the relation between the rates and each of the 10 most common readmission diagnoses across hospitals. Regression models were weighted by the inverse of the standard error of the hospital level percentage of each of the 10 most common readmission diagnoses. After univariate analysis, we fitted additional weighted regression models that were adjusted

for other hospital characteristics besides the 30 day risk standardized readmission rate including teaching status, urban/rural location, ownership status (private, not for profit, public), safety net status, critical access status, proportion of patients receiving Medicaid health insurance, proportion of African-American patients, and hospital volume with regard to the number of index admissions for each condition. Safety net hospitals in the US provide care for a high proportion of uninsured, underinsured, or Medicaid patients; as has been done previously, we defined safety net hospitals as public or private hospitals with an annual Medicaid caseload >1 SD above their respective state's mean private hospital Medicaid caseload.^{20 21}

Readmission timing by hospital performance

We calculated a weighted average of hospitals' median time to readmission for hospitals with high, average, and low performance by 30 day risk standardized readmission rate. We calculated summary statistics for each hospital performance level. We used the Kruskal-Wallis test to examine whether median time to readmission differed between hospital performance groups. We also developed regression models of the relation between hospital level risk standardized readmission rates and hospital level median time to readmission. Models were weighted by the number of readmissions for each hospital. After univariate analysis, we fitted additional weighted regression models that were adjusted for the other hospital characteristics described above.

All significance levels for the regression models were two sided with a P value <0.05, and analyses were carried out with SAS 9.2 (SAS Institute, Cary, NC).

Results

In the 30 days after the index admission, we identified 320 003 readmissions after 1 291 211 index admissions for heart failure (4041 hospitals), 102 536 readmissions after 517 827 index admissions for acute myocardial infarction (2378 hospitals), and 208 438 readmissions after 1 135 932 index admissions for pneumonia (4283 hospitals). Appendix 2 provides flow diagrams that identify hospital exclusions for each cohort. The average 30 day risk standardized readmission rates were 24.7%, 19.8%, and 18.2% after index admissions for heart failure, acute myocardial infarction, or pneumonia, respectively (table 1). Hospitals in the acute myocardial infarction cohort were the least likely to be designated as rural or critical access. Compared with high performing hospitals, low performers for heart failure, acute myocardial infarction, and pneumonia had a higher percentage of African-American patients.

Readmission diagnoses by hospital performance

The percentage of readmissions for the 10 most common diagnostic categories was similar across hospital performance groups for heart failure (fig 1), acute myocardial infarction (fig 2), and pneumonia (fig 3). For high, average, and low performing hospitals, the percentage of readmissions for cardiovascular disease after index admission for heart failure was 53.0%, 52.7%, and 53.5%, respectively, while that for acute myocardial infarction was 55.1%, 53.6%, and 51.0%, respectively. The percentage of readmissions for pulmonary disease after index admission for pneumonia was 39.2%, 38.6%, and 37.0% for high, average, and low performing hospitals, respectively.

We found similarly small relations between hospital performance across the range of 30 day risk standardized readmission rates and readmission diagnoses. Univariate analyses (table F in appendix 1) showed that for every standard deviation increase in rate, readmissions for common diagnostic categories changed between 0% and 0.6%. These associations were typically further reduced in multivariate analyses (table G in appendix 1). Rural and critical access hospitals were found to have a unique spectrum of readmissions. For example, after admission for acute myocardial infarction, rural and critical access hospitals readmitted 6.6% and 9.6%, respectively, more patients for recurrent acute myocardial infarction. Readmission for recurrent pneumonia was also more common at these institutions.

Readmission timing by hospital performance

There were no notable differences in the weighted median time to readmission among high, average, and low performing hospitals for heart failure (12.6, 12.3, and 12.1 days, respectively; $P=0.11$) or acute myocardial infarction (9.8, 10.1, and 10.0 days, respectively; $P=0.12$). High performing hospitals for pneumonia had longer weighted median times to readmission by 1.4 days compared with low performing hospitals (12.9 days v 11.5 days, respectively; $P<0.001$) (figs 4, 5, and 6, respectively).

We found similar relations between hospital performance across the range of 30 day risk standardized readmission rates and median time to readmission. Univariate analysis showed that for every standard deviation increase in rate, the median time to readmission changed by 0.13, 0.04, and 0.23 days after admission for heart failure, acute myocardial infarction, or pneumonia, respectively. Associations were similar in multivariate analyses (table 2). All other hospital characteristics were associated with changes in median time to readmission by ≤ 0.45 days.

Discussion

Principal findings

In contemporary practice, hospitals with different 30 day readmission rates after index admissions for heart failure, acute myocardial infarction, or pneumonia have a similar distribution of readmissions with regard to their diagnoses and timing. Our national study examined readmission diagnoses and timing patterns across hospitals with different performance profiles. The findings extend previous work on the predictors of hospital performance¹⁷⁻¹⁹ by showing that high performing hospitals with low 30 day risk standardized readmission rates maintain a similar pattern of readmission diagnoses and timing as lower performing institutions. High performers have not empirically achieved low overall rates of readmission by reducing readmissions from specific diagnoses or time periods after discharge. As readmissions result from a diverse spectrum of conditions and occur throughout the month after admission,¹⁴⁻²⁵ our results suggest that hospitals might best achieve low 30 day readmission rates by using general strategies or capacities that apply broadly across potential readmission diagnoses and time periods after discharge.

Extension of previous research

We have extended previous research describing the diverse spectrum of readmission diagnoses¹⁴⁻²⁵ by showing that medical conditions that cause readmission remain similar across hospitals with different characteristics. For example, in multivariate

analysis we found that the percentage of readmissions for each of the 10 most common readmission diagnoses in heart failure, acute myocardial infarction, and pneumonia cohorts varied by less than 1% at safety net hospitals compared with non-safety net hospitals. We additionally found that every standard deviation increase in hospitals' percentage of patients from ethnic minority groups and patients with Medicaid health insurance resulted in similarly small changes in the percentage of readmissions for common readmission diagnoses. These results show that hospitals serving minority groups have similar readmission patterns, despite having higher overall rates of readmission.²⁶ Strategies to reduce readmission could therefore account for a similar underlying spectrum of readmission diagnoses across many different care settings.

Implications for reducing readmissions

Our findings could explain why the combination of broad based²⁷ and longitudinal strategies applicable to a range of potential readmission diagnoses throughout the period after discharge have, in intervention studies, shown efficacy in lowering hospital readmissions while disease specific or time limited interventions have been often unsuccessful. Rich and colleagues showed that complementary interventions delivered by a nurse, dietician, social worker, and geriatrician in the hospital as well as longitudinal follow-up with home care and study teams reduced readmissions after hospital admission for heart failure.²⁸ Similarly, Coleman and colleagues found that the combination of inpatient visits and visits after discharge by a nurse transition coach, assistance with self management of drug treatment, education about potential "red flag" conditions that require expedited follow-up, and the creation of a patient owned medical record designed to bridge care settings lowered readmission in patients with 11 common conditions.²⁹

Our findings could also explain why disease specific or time limited interventions have generally been found to be less efficacious, as the highest performing hospitals were not especially good at reducing readmissions for particular medical conditions or time periods after discharge. The wide breadth of diagnoses and time periods associated with readmission¹⁴⁻²⁵ implies that overall rates of readmission cannot be reduced by lowering only a small subset of readmissions. It is therefore not surprising that major trials of disease specific or singular interventions after discharge have had disappointing results for all cause readmission.³⁰⁻³² In particular, well designed trials of telemonitoring to identify early evidence of heart failure decompensation have not shown reduced rates of all cause readmission, despite involving highly engaged patients and healthcare providers.³⁰⁻³²

Our results are also consistent with those of previous studies linking high hospital performance with organizational and cultural characteristics that would be expected to apply broadly to a range of conditions and times after hospital admission. Curry and colleagues conducted a qualitative analysis to identify potential drivers of low risk standardized mortality rates for acute myocardial infarction⁶ and found that high and low performing hospitals were not differentiated by disease specific protocols or processes of care but rather by shared organizational values of providing high quality care, senior managerial provision of financial and non-financial resources, multidisciplinary teams with empowered non-physician providers, strong internal communication and coordination, and commitment to problem solving. The presence of organizational characteristics with the potential to exert broad influence across readmission diagnoses and time periods after discharge among

high performing hospitals was confirmed in a cross sectional survey of more than 500 hospitals.⁷

The reasons underlying the greater percentage of readmissions for recurrent acute myocardial infarction and recurrent pneumonia at rural and critical access hospitals are unknown. As these hospitals are less likely to have catheterization facilities,³³ patients treated there for acute myocardial infarction might be less likely to undergo revascularization and more likely to experience reinfarction. Rural hospitals might also less often follow acute myocardial infarction process measures.³⁴⁻³⁶ The reasons for greater recurrence of pneumonia at rural hospitals are less clear but could relate to worse performance on evidence based care processes,³³ differences in use of resources after acute care,³⁷ or greater difficulties accessing care.³⁸⁻³⁹ Despite these uncertainties, the different composition of readmission diagnoses at these facilities could be useful in guiding disease surveillance after hospital discharge.

Social and hospital factors in readmission

Our finding of similar patterns of readmission regardless of hospital readmission performance could imply deficiencies in the Centers for Medicare and Medicaid Services algorithms we used to calculate risk standardized readmission rates. Differences in hospital performance could fundamentally reflect differences in social and environmental factors experienced by patients at high and low performing hospitals rather than intrinsic signals of hospital quality. There is, however, controversy about the importance of social and environmental factors at the hospital level. The predictive power of these factors at the patient level has been inconsistent.¹⁷⁻⁴⁶ Even clinical factors that describe illness severity at the time of admission, such as vital signs and results of laboratory testing, have not been shown to provide substantial incremental value in predicting rates of hospital readmission compared with administrative claims data.¹⁰⁻⁴⁷

In contrast, there is evidence that hospitals and hospital organizational characteristics can impact rates of readmission. For example, between 1997 and 2010 Veterans Affairs hospitals significantly lowered 30 day readmission rates for heart failure, acute myocardial infarction, pneumonia, and other common conditions.⁴⁸ Moreover, hospitals that care for older adults lowered 30 day readmission rates in the last quarter of 2012 in the face of new financial penalties designed to reduce readmission.⁴⁹ In addition, many hospitals with a high percentage of medically underserved patients from either racial and ethnic minority groups or low socioeconomic strata nonetheless have low risk standardized readmission rates.⁴ High performing hospitals might possess particular organizational characteristics and capacities that are responsible for their low rates of adverse outcomes⁶ and are consistent with organizational performance goals for the highest performing healthcare organizations.⁵⁰

Study limitations

There are potential limitations to this analysis. We restricted our study to beneficiaries of Medicare fee for service health insurance at hospitals with more than 25 index admissions during the study period, so conclusions drawn from this population might not apply to others such as younger patients, patients admitted with different conditions, or patients at the smallest hospitals. We also did not include information from hospitals with no readmissions during the study period, which included 708 hospitals (15.9% of all hospitals) treating acute myocardial infarction and 313 hospitals (6.5% of all hospitals) treating pneumonia. Most of these hospitals had small case volumes as the median number of admissions for acute

myocardial infarction and pneumonia at these institutions was three and 30, respectively. Only 79 hospitals (1.8% of all hospitals) caring for patients with acute myocardial infarction and 162 hospitals (3.4% of hospitals) caring for patients with pneumonia had more than 25 index admissions and no readmissions during the study period. More than 93% of these “super performing” hospitals for acute myocardial infarction and 96% of these “super performing” hospitals for pneumonia did not submit survey data to the American Hospital Association and are therefore difficult to characterize. Study conclusions might therefore not apply to hospitals not participating in the annual survey of the American Hospital Association. This study of more than 600 000 hospital readmissions from more than 4000 hospitals, however, is the largest of its kind and shows consistent findings across the most common cardiopulmonary conditions. Though we relied on claims data to assign diagnoses to admissions, administrative codes have been validated for cardiovascular and pulmonary diagnoses.⁵¹⁻⁵³ We did not exclude all potential planned readmissions such as those for treatment with chemotherapy or radiotherapy. However, we did not expect these elective admissions to be common soon after incident heart failure, myocardial infarction, or major infection such as pneumonia. We did exclude readmissions for revascularization after admission for acute myocardial infarction. Lastly, there might be concerns that the hierarchical modeling approach used by the Centers for Medicare and Medicaid Services obscures relations because findings are weighted by hospital volume, thereby making it less likely that small hospitals are considered high or low performers. This approach, however, was approved by the National Quality Forum and an independent committee of statisticians to reduce the likelihood of finding spurious results based on small sample volumes at certain hospitals. Moreover, we observed a substantial range of readmissions with this method. Our goal was not to further validate the readmission performance algorithms created by the Centers for Medicare and Medicaid Services but to understand how differences in hospitals’ risk standardized readmission rates relate to readmission patterns.

Conclusions

We found that in contemporary practice, readmission diagnoses and timing after admission for heart failure, acute myocardial infarction, or pneumonia do not differ by hospital 30 day risk standardized readmission rates. Rather than having a smaller number of readmissions from particular diagnoses or time periods after discharge, high performing hospitals have fewer readmissions across the broad spectrum of readmission diagnoses throughout the post-discharge period. These findings suggest that lower readmission rates might best be achieved through use of general strategies and capacities that lower readmission risk globally rather than for specific diagnoses or time periods after admission.

Contributors: KD and HMK devised the study concept and design; analyzed and interpreted the data; drafted the paper; and are guarantors. AFH and ZL performed all statistical analyses. AFH, ZL, HB, JSR, LIH, JAB-F, NK, LGS, LMB, SMB, and EED analyzed and interpreted the data and critically revised the manuscript for important intellectual content. HMK obtained funding, acquired the data, and supervised the study. KD and HMK had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analyses.

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What is already known on this topic

Rates of readmission after hospital admission for heart failure, acute myocardial infarction, and pneumonia vary greatly across hospitals

It is unknown whether high performing hospitals with low 30 day readmission rates have a lower proportion of readmissions from specific diagnoses and in certain time periods after admission or instead have a similar distribution of readmission diagnoses and timing as low performing institutions with high rates of readmission

What this study adds

The distribution of readmissions by diagnosis and the median time to readmission were similar across hospital performance categories for all three conditions studied

Rather than have a smaller number of readmissions from particular diagnoses or time periods after discharge, high performing hospitals have fewer readmissions across the broad spectrum of readmission diagnoses throughout the post-discharge period

Lower readmission rates might be best achieved through the use of general strategies and capacities that lower readmission risk globally rather than interventions that target specific diagnoses or time periods after admission

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Ethical approval: The study received institutional review board approval through the Yale University Human Investigation.

Transparency declaration: KD affirms that this manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

Data sharing: No additional data available.

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Tables

Table 1 | Hospital characteristics by reason for index admission and performance category for readmissions (high performing hospitals have low rates of readmission). All numbers are percentages unless stated otherwise

	Hospital performance categories			
	All	High performing	Average performing	Low performing
Heart failure				
No of hospitals	4041	133	3692	216
Median (IQR):				
30 day risk standardized readmission rate*	24.7 (23.6-26.0)	21.1 (20.3-21.6)	24.6 (23.6-25.8)	28.9 (27.9-29.5)
Annual heart failure volume	64.0 (27.7-146.3)	202.0 (158.3-311.3)	57.0 (25.5-130.0)	170.5 (99.5-293.5)
Medicaid†	15.8 (10.5-20.6)	16.1 (11.2-19.6)	15.7 (10.3-20.3)	18.8 (13.4-24.9)
African-American‡	2.8 (0.0-12.2)	3.2 (0.7-9.6)	2.5 (0.0-11.2)	11.7 (2.7-32.9)
Rural hospital	22.4	1.5	23.7	10.6
Critical access hospital	23.1	1.5	25.1	1.9
Teaching hospital	18.7	39.8	16.8	37.5
Safety net hospital§	29.8	18.0	30.5	25.0
Publicly owned hospital	22.1	12.0	22.9	13.4
Not for profit hospital	62.1	78.9	61.1	68.1
Privately owned hospital	15.9	9.0	16.0	18.5
AMI				
No of hospitals	2378	73	2225	80
Median (IQR):				
30 day risk standardized readmission rate*	19.8 (18.7-21.1)	16.1 (15.7-16.6)	19.8 (18.8-21.0)	24.6 (23.7-25.6)
Annual acute myocardial infarction volume	44.3 (19.3-96.0)	152.3 (110.7-256.0)	40.0 (18.3-87.3)	127.5 (64.3-213.0)
Medicaid†	17.5 (12.2-21.7)	14.9 (11.3-19.1)	17.5 (12.1-21.7)	19.5 (16.3-29.4)
African-American‡	3.1 (0.5-9.7)	1.4 (0.4-3.5)	3.0 (0.5-9.2)	14.2 (4.5-30.6)
Rural hospital	5.1	0.0	5.3	2.5
Critical access hospital	2.0	0.0	2.1	0.0
Teaching hospital	29.1	39.7	27.3	31.3
Safety net hospital§	22.0	12.3	22.2	26.3
Publicly owned hospital	13.0	8.2	13.3	8.8
Not for profit hospital	69.4	80.8	68.6	82.5
Privately owned hospital	17.6	11.0	18.2	8.8
Pneumonia				
No of hospitals	4283	71	4040	172
Median (IQR):				
30 day risk standardized readmission rate*	18.2 (17.3-19.1)	15.1 (14.6-15.5)	18.2 (17.3-19.2)	22.3 (22.1-23.0)
Annual pneumonia volume	65.3 (33.0-119.3)	157.0 (110.3-209.0)	61.3 (31.7-112.7)	140.0 (95.8-202.5)
Medicaid†	15.6 (10.1-20.2)	15.7 (11.8-19.5)	15.5 (10.0-20.2)	17.6 (12.3-21.8)
African-American‡	1.6 (0.0-7.5)	1.1 (0.2-3.9)	1.5 (0.0-7.2)	6.9 (1.3-16.0)
Rural hospital	25.3	4.2	26.1	15.1
Critical access hospital	26.8	7.0	28.1	3.5
Teaching hospital	17.8	38.0	16.6	36.0
Safety net hospital§	31.4	30.9	31.8	21.5
Publicly owned hospital	24.0	21.1	24.4	14.5
Not for profit hospital	61.0	73.2	60.4	70.3
Privately owned hospital	15.1	5.6	15.2	15.1

IQR=interquartile range.

Table 1 (continued)

	Hospital performance categories			
	All	High performing	Average performing	Low performing
*Over three years.				
†Median hospital proportion of patients with Medicaid health insurance.				
‡Median hospital proportion of African-American patients.				
§Safety net hospitals in US provide care for high proportion of uninsured, underinsured, or Medicaid patients; we have defined safety net hospitals as public or private hospitals with annual Medicaid caseload >1 SD above their respective state's mean private hospital Medicaid caseload.				

Table 2| Relation between hospital characteristics and median time to readmission after index admission to hospital for heart failure, acute myocardial infarction, or pneumonia

Hospital characteristic	Coefficient for change in median time to readmission in days (95% CI)		
	Heart failure	Acute myocardial infarction	Pneumonia
30 day risk standardized readmission rate*	-0.15 (-0.19 to -0.10)	0.03 (-0.05 to 0.11)	-0.23 (-0.29 to -0.17)
Annual hospital volume†	0.01 (-0.03 to 0.05)	-0.11 (-0.17 to -0.05)	0.07 (0.02 to 0.12)
% Medicaid‡	-0.06 (-0.12 to 0.01)	-0.01 (-0.13 to 0.10)	-0.07 (-0.16 to 0.01)
% African-American§	0.11 (0.06 to 0.17)	0.04 (-0.07 to 0.14)	0.03 (-0.04 to 0.10)
Rural hospital¶	0.10 (-0.14 to 0.34)	-0.25 (-1.00 to 0.50)	0.24 (-0.00 to 0.48)
Critical access hospital	-0.07 (-0.36 to 0.21)	0.45 (-1.02 to 1.92)	0.29 (0.01 to 0.56)
Teaching hospital**	-0.09 (-0.21 to 0.03)	-0.22 (-0.40 to -0.03)	-0.15 (-0.30 to -0.01)
Safety net hospital††	0.07 (-0.15 to 0.29)	0.05 (-0.32 to 0.42)	0.22 (-0.06 to 0.49)
Publicly owned hospital‡‡	-0.05 (-0.32 to 0.22)	-0.08 (-0.55 to 0.40)	-0.32 (-0.66 to 0.02)
Not for profit hospital§§	-0.02 (-0.36 to 0.21)	0.19 (-0.08 to 0.45)	-0.13 (-0.32 to 0.05)

*Over three years. Coefficient for change for every SD increase in rate. For example, for heart failure readmission cohort, when rate increased by 1 SD, hospital median time to readmission decreased by 0.148 days.

†Total No of admissions for index condition 2007-09 divided by 3. Coefficient for change for every increase in annual volume for index condition by 1 SD.

‡Proportion of patients with Medicaid health insurance cared for by facility as defined with 2008 American Hospital Association data. Coefficient for change for every 1 SD increase in proportion of hospital patients that have Medicaid health insurance.

§Proportion of African-American patients cared for by facility in 2007-09. Coefficient for change every 1 SD increase in proportion of African-American hospital patients.

¶Rural v urban.

**Teaching v non-teaching hospitals

††Safety net hospitals in US provide care for high proportion of uninsured, underinsured, or Medicaid patients; we have defined safety net hospitals as public or private hospitals with annual Medicaid caseload >1 SD above their respective state's mean private hospital Medicaid caseload.

‡‡Publicly v privately owned hospitals.

§§Not for profit v privately owned hospitals.

Figures

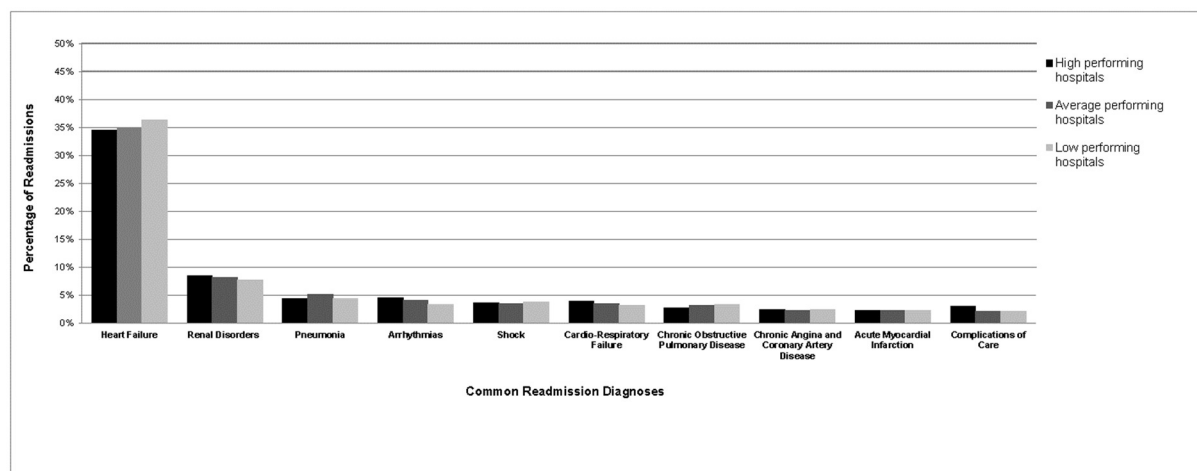


Fig 1 Ten most common readmission diagnoses for high, average, and low performing hospitals after admission for heart failure. Numbers rounded to nearest percentage point. High performing hospitals have 30 day risk standardized readmission rates lower than national average rate with >95% probability. Low performing hospitals have 30 day risk standardized readmission rates higher than national average rate with >95% probability. All remaining hospitals are considered average. For each hospital, we calculated performance separately for heart failure, acute myocardial infarction, and pneumonia cohorts

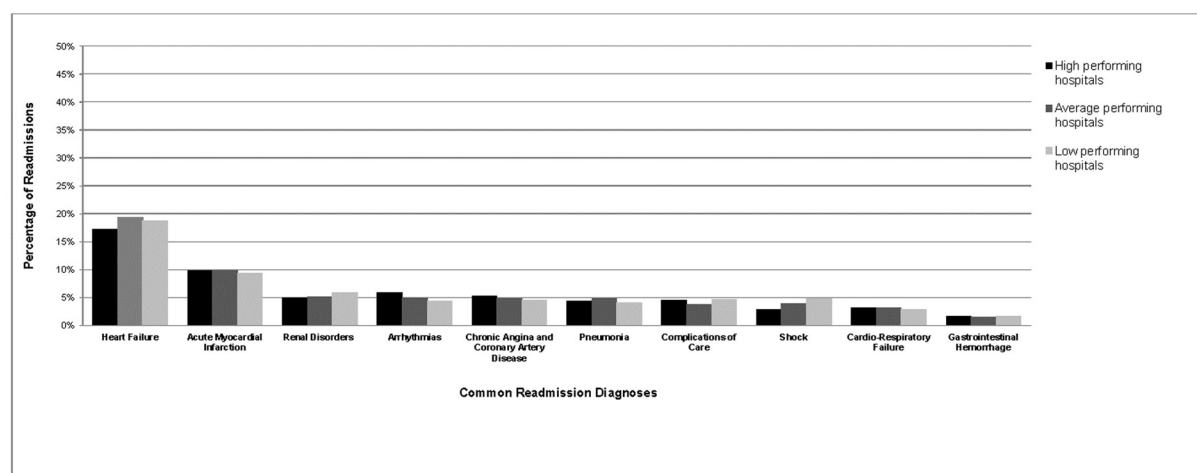


Fig 2 Ten most common readmission diagnoses for high, average, and low performing hospitals after admissions for acute myocardial infarction. See also legend for fig 1

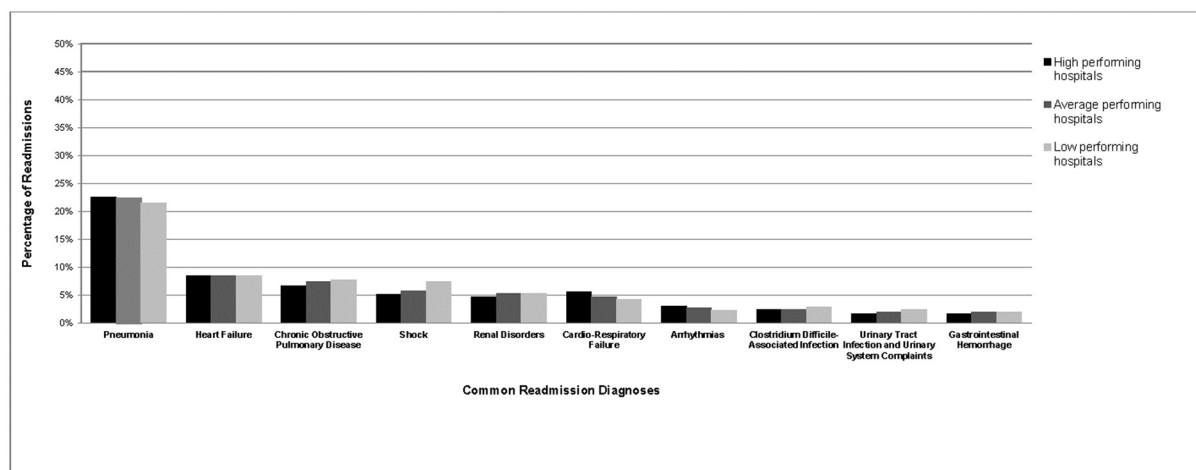


Fig 3 Ten most common readmission diagnoses for high, average, and low performing hospitals after admission for pneumonia. See also legend for fig 1

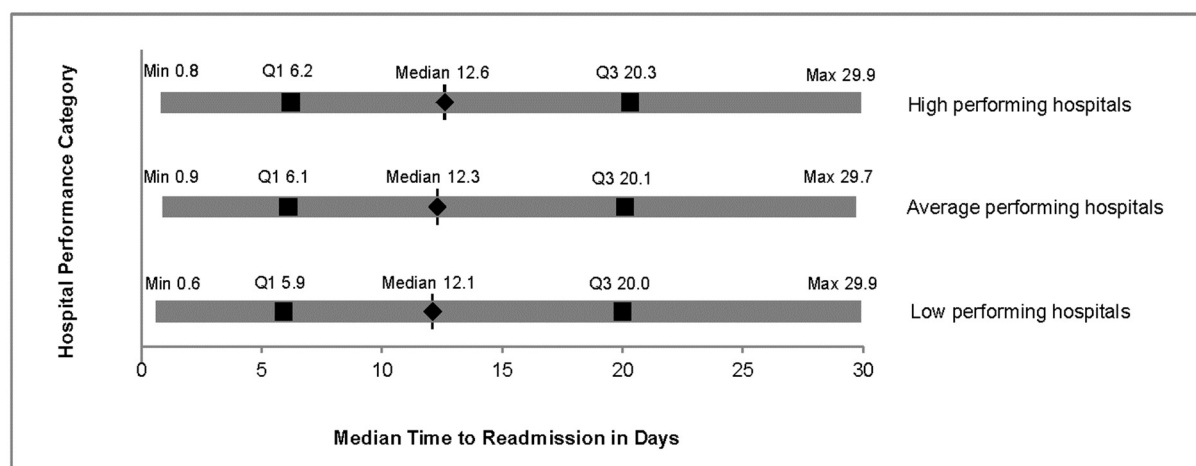


Fig 4 Weighted median time to readmission for high, average, and low performing hospitals after admission for heart failure. High performing hospitals have 30 day risk standardized readmission rates lower than national rate with >95% probability. Low performing hospitals have 30 day risk standardized readmission rates higher than national average rate with >95% probability. All remaining hospitals are considered average. For each hospital, we calculated performance separately for heart failure, acute myocardial infarction, and pneumonia cohorts. Weighted median time to readmission denoted by black diamond; interquartile range denoted by black squares; range denoted by gray bar

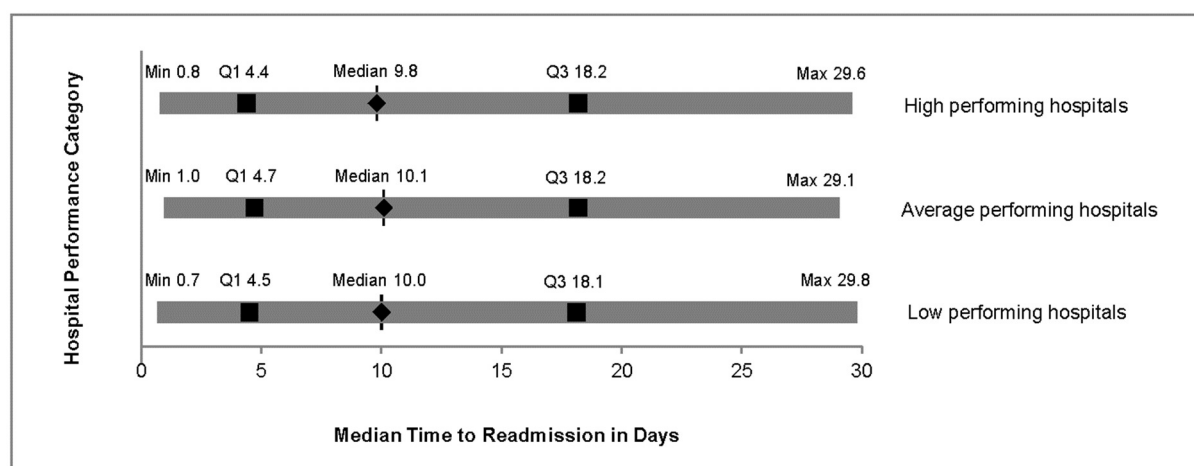


Fig 5 Weighted median time to readmission for high, average, and low performing hospitals after admission for acute myocardial infarction. See also legend for fig 4

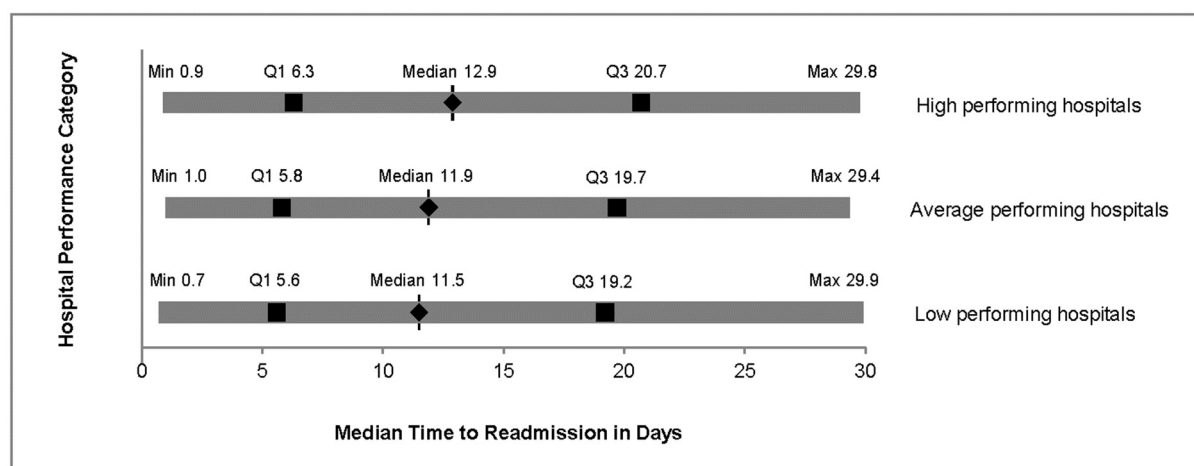


Fig 6 Weighted median time to readmission for high, average, and low performing hospitals after admission for pneumonia. See also legend for fig 4