Supplementary Appendix

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

Supplement to: Jha AK, Orav EJ, Epstein AM. Public reporting of discharge planning and rates of readmissions.
N Engl J Med 2009;361:2637-45.

Technical Appendix

Discharge Planning:
We used two types of performance data on discharge planning from the HQA dataset: a chart-based process measure that examines whether patients hospitalized with CHF received adequate discharge instructions as noted in the medical record and a patient-reported measure that is a composite of answers to two questions about the adequacy of discharge planning. To meet the performance criteria on the chart-based measure, the medical record must state that the patient or a caregiver was provided with written instructions or educational material prior to discharge addressing the following: activity level, diet, discharge medications, follow-up appointment, weight monitoring, and what to do if symptoms worsen.[1] For each hospital, CMS calculates a score representing the proportion of CHF patients whose charts meet the criteria for adequate discharge instructions.

The second discharge planning measure came from the HCAHPS survey, which asks patients about the quality of discharge planning. This measure was comprised of two questions: "did the hospital staff ask you about whether you would have the help you needed when you left the hospital" and "did you receive written information about the symptoms or health problems to monitor after leaving the hospital". For each hospital, CMS calculates a composite score, representing the proportion of patients who answered yes to both questions.[2]

Risk-Adjusted Readmission Rates:
To identify readmissions, we examined every hospitalization with the primary discharge diagnosis of CHF (ICD-9 codes 398.91, 404.x1, 404.x3, 428.0 to 428.9) or pneumonia (ICD-9 codes 480 to 486) where the patient was discharged prior to December 1 (to ensure that all patients had at least 30 days to be readmitted). We excluded all patients who died during that hospitalization. We then analyzed all-cause readmissions within 30 days of discharge using the Elixhauser adjustment scheme, where the likelihood of being readmitted was adjusted for patient characteristics including age, gender, race, and the presence or absence of up to 29 co-morbidities.[3,4] The Elixhauser adjustment was developed for mortality and is widely accepted for its good predictive validity (see "Risk-adjusted model for readmission rate" below for greater details and evidence of validity).[3,4] Because there is no consistent and validated approach used in prior work for risk-adjustment of readmissions, we presumed that age and the presence of a wide range of comorbid conditions are likely also to be factors associated with a higher risk of readmission**.**

We built our risk-adjusted models for readmission rates separately for CHF patients and pneumonia patients, but used the same set of variables. Our logistic regression model was as follows:

$y = \alpha + \beta_1 \text{ age} + \beta_2 \text{ gender} + \beta_3 \text{ race} + \beta_4 \text{ Comorib1} + \ldots\ldots \beta_{32}\, e_i$

where y is the log-odds of being readmitted within 30 days (yes or no), α is the intercept, and the βetas are the coefficients of each of the variables in the model. The βeta coefficients are shown below in Tables 1a-b. We calculated rates of readmission for each hospital. We also calculated rates for patients in a given HRR, controlling for clustering within hospitals.

We found that the Elixhauser scheme had very good predictive ability: we categorized all patients into deciles by their predicted likelihood of readmission and found a clear and consistent relationship between the predicted and observed readmission rate. For example, among CHF patients, the observed readmission rates ranged from 13.2% (in the lowest predicted decile) to 52.0% (highest predicted decile), increasing in a monotonic fashion across the ten groups. Similarly, the observed rate among pneumonia patients ranged from 13.1% (lowest predicted decile) to 26.8% (highest predicted decile), increasing in a monotonic fashion with each increasing decile of predicted readmission.

Calculation of HRR-specific readmission rates:

In our calculation of risk-adjusted readmission rates among the 298 Hospital Referral Regions (HRRs) with adequate sample size (>100 patients discharged with CHF and pneumonia), we built models similar to the one described above. These patient-based models were specified as follows:

$y = \alpha + \beta_1$ age + β_2 gender + β_3 race + β_4 Comorib1 +……. β_{32} HRR1 + β_{33} HRR2 + β_{329} HRR298 + β_{330} e_i

where y is the log-odds of being readmitted within 30 days (yes or no), α is the intercept, and the βetas are the coefficients of each of the variables in the model. Using SUDAAN, we were able to specify, for each HRR, its projected readmission rates if all the patients in the database (national sample) had all been seen in that HRR.

Analyses of the association between discharge planning and readmissions.

In our analysis of whether the individual discharge planning metrics were associated with readmission rates, we again built separate patient-based models for each discharge metric with readmission as the outcome and the discharge metric as the primary predictor. In each model, we used the Elixhauser adjustment scheme (see "Risk-adjusted model for readmission rate" below for further information regarding validity). We subsequently further adjusted for the same seven variables used in the analyses above (on predictors of discharge planning), choosing them for the same reasons: they were either likely to be associated with discharge activities or had previously shown to be related to similar quality metrics.

Again, we built our risk-adjusted models for readmission rates separately for CHF patients and pneumonia patients, using the same set of variables. Our logistic regression model was as follows:

$y = \alpha + \beta_1$ age + β_2 gender + β_3 race + β_4 Comorib1 +…….β_{32} Comorb 29 + + β_{33} Quartile2 + β_{34} Quartile3 + β_{35} Quartile3 e_i

where y is the log-odds of being readmitted within 30 days (yes or no), α is the intercept, and the βetas are the coefficients of each of the variables in the model. β_{33}, β_{34}, and β_{35} represent the indicator variables for the quartile of HQA discharge scores (in an alternative model, the quartile of HCAHPS discharge instructions) as the covariate of interest. Each patient was assigned the HQA/HCAHPS score for his or her hospital. The βeta coefficients are shown below in Tables 1a-b. The significance of the association between HQA quartiles and readmissions was calculated from this model using a global 3-degree of freedom test across the 4 quartiles. A similar test was carried out for the HCAHPS quartiles. In addition, the risk-adjusted readmission rate for each quartile was calculated by averaging the logistic probabilities across all patients in the database using the estimated dummy indicator variable for that quartile. Effectively, this estimates the average chance of readmission if all patients in the database were seen by the hospitals in a specific HQA of HCAHPS quartile. We also examined HQA and HCAHPS scores as continuous variables. The results were qualitatively similar.

Analyses of the projected impact of improving discharge planning on readmissions.

In these analyses, we first calculated, for each hospital, its raw, unadjusted readmission rates. We subsequently built logistic regression models as follows:

$y = \alpha + \beta_1$ age + β_2 gender + β_3 race + β_4 Comorib1 +……β_{32} HCAHPS + β_{33} e_i

where β_{32} represents the coefficient of the relationship between HCAHPS performance and readmission rate.

We subsequently calculated, for each hospital, the difference between its HACHPS score and the 90th percentile score and multiplied this difference by $\beta_{32,}$ which represented the odds ratio of improvement.

We then calculated for each hospital its improved readmission rate if the HCAHPS score had been at the 90th percentile.

We subsequently subtracted the projected "improved" readmission rate from the actual readmission rate and multiplied this by number the total number of admissions to calculate the "excess" readmissions that could be eliminated if each hospital's HCAHPS performance increased to the 90th percentile nationally.

Technical Appendix Table 1a: Description of Congestive Heart Failure Model Coefficients

Coefficient Description	HQA β, (SE)	HCAHPS β, (SE)
Intercept	-1.43 (0.12)	-1.37 (0.12)
Age	0.00 (0.0)	0.00 (0.0)
White	0.04 (0.09)	0.05 (0.09)
Black	0.08 (0.10)	0.08 (0.10)
Others	-0.02 (0.11)	-0.02 (0.11)
Asian	0.02 (0.11)	0.00 (0.11)
Hispanic	0.13 (0.10)	0.12 (0.10)
Native American	0.11 (0.12)	0.12 (0.12)
Male	-0.03 (0.01)	-0.03 (0.01)
Congestive Heart Failure	1.15 (0.01)	1.15 (0.01)
Valvular Disease	0.06 (0.02)	0.06 (0.02)
Pulmonary Circulation Disease	-0.19 (0.03)	-0.19 (0.03)
Peripheral Vascular Disease	0.01 (0.02)	0.01 (0.02)
Paralysis	0.18 (0.04)	0.18 (0.04)
Other Neurological Disorders	0.03 (0.02)	0.03 (0.02)
Chronic Pulmonary Disease	0.08 (0.01)	0.08 (0.01)
Diabetes without Chronic Complications	-0.01 (0.01)	-0.01 (0.01)
Diabetes with Chronic Complications	0.01 (0.02)	0.01 (0.02)
Hypothyroidism	-0.08 (0.02)	-0.08 (0.02)
Renal Failure	0.57 (0.02)	0.57 (0.02)
Liver Disease	0.14 (0.05)	0.14 (0.05)
Lymphoma	0.11 (0.05)	0.11 (0.05)
Metastatic cancer	0.16 (0.04)	0.16 (0.04)
Solid Tumor without Metastasis	0.05 (0.03)	0.05 (0.03)
Rheumatoid Arthritis/ Collagen Vascular Diseases	-0.14 (0.04)	-0.14 (0.04)
Coagulopathy	0.16 (0.03)	0.16 (0.03)
Obesity	-0.28 (0.03)	-0.28 (0.03)
Weight loss	0.31 (0.03)	0.31 (0.03)
Fluid and Electrolyte Disorders	0.25 (0.01)	0.25 (0.01)
Chronic Blood Loss, Anemia	0.14 (0.04)	0.14 (0.04)
Deficiency Anemias	-0.02 (0.01)	-0.02 (0.01)
Alcohol Abuse	-0.24 (0.06)	-0.25 (0.06)
Drug Abuse	0.31 (0.12)	0.31 (0.12)
Psychoses	0.22 (0.04)	0.22 (0.04)
Depression	0.03 (0.03)	0.03 (0.03)
Hypertension	-0.30 (0.01)	-0.30 (0.01)
Highest discharge quartile	0.03 (0.02)	-0.11 (0.02)
Second highest discharge quartile	0.00 (0.02)	-0.08 (0.02)
Third highest discharge quartile	-0.02 (0.02)	-0.05 (0.02)
New England hospital location	0.18 (0.02)	0.19 (0.02)
Midwest hospital location	0.13 (0.02)	0.15 (0.02)
South hospital location	0.11 (0.02)	0.11 (0.02)
6-99 hospital beds	-0.04 (0.03)	-0.02 (0.03)
100-399 hospital beds	0.02 (0.02)	0.02 (0.02)
Presence of MCU	-0.03 (0.02)	-0.03 (0.02)
Teaching hospital	0.02 (0.02)	0.03 (0.02)
Urban hospital	-0.14 (0.04)	-0.14 (0.04)
For-profit hospital	0.05 (0.03)	0.03 (0.03)
Non-profit, non-government	-0.03 (0.02)	-0.03 (0.02)

β is the parameter estimate. SE is the Standard Error.

Technical Appendix Table 1b: Description of Pneumonia Model Coefficients

Coefficient Description	HQA (β, (SE)	HCAHPS (β, (SE)
Intercept	-1.96 (0.13)	-1.91 (0.13)
Age	0.01 (0.0)	0.01 (0.0)
White	0.13 (0.10)	0.13 (0.10)
Black	0.31 (0.10)	0.31 (0.10)
Others	-0.08 (0.12)	-0.09 (0.12)
Asian	0.00 (0.11)	0.00 (0.11)
Hispanic	0.17 (0.11)	0.17 (0.11)
Native American	0.27 (0.13)	0.28 (0.13)
Male	0.00 (0.01)	0.00 (0.01)
Congestive Heart Failure	0.19 (0.01)	0.19 (0.01)
Valvular Disease	-0.19 (0.02)	-0.19 (0.02)
Pulmonary Circulation Disease	-0.07 (0.03)	-0.07 (0.03)
Peripheral Vascular Disease	0.03 (0.02)	0.04 (0.02)
Paralysis	0.16 (0.04)	0.16 (0.04)
Other Neurological Disorders	-0.04 (0.02)	-0.04 (0.02)
Chronic Pulmonary Disease	-0.11 (0.01)	-0.11 (0.01)
Diabetes without Chronic Complications	-0.02 (0.01)	-0.02 (0.01)
Diabetes with Chronic Complications	0.00 (0.03)	0.00 (0.03)
Hypothyroidism	-0.19 (0.02)	-0.19 (0.02)
Renal Failure	0.64 (0.03)	0.64 (0.03)
Liver Disease	0.05 (0.05)	0.05 (0.05)
Lymphoma	0.06 (0.04)	0.06 (0.04)
Metastatic Cancer	0.28 (0.03)	0.28 (0.03)
Solid Tumor without Metastasis	0.14 (0.03)	0.14 (0.03)
Rheumatoid Arthritis/Collagen Vascular Diseases	-0.06 (0.03)	-0.06 (0.03)
Coagulopathy	0.16 (0.03)	0.16 (0.03)
Obesity	-0.23 (0.04)	-0.23 (0.04)
Weight loss	0.45 (0.02)	0.45 (0.02)
Fluid and Electrolyte Disorders	-0.06 (0.01)	-0.06 (0.01)
Chronic Blood Loss, Anemia	0.50 (0.04)	0.50 (0.04)
Deficiency Anemias	-0.06 (0.01)	-0.06 (0.01)
Alcohol Abuse	-0.17 (0.06)	-0.16 (0.06)
Drug Abuse	0.22 (0.09)	0.21 (0.09)
Psychoses	0.12 (0.03)	0.12 (0.03)
Depression	-0.04 (0.02)	-0.04 (0.02)
Hypertension	-0.38 (0.01)	-0.39 (0.01)
Highest discharge quartile	0.04 (0.02)	-0.08 (0.02)
Second highest discharge quartile	0.02 (0.02)	-0.04 (0.02)
Third highest discharge quartile	0.01 (0.02)	-0.06 (0.02)
New England hospital location	0.19 (0.03)	0.19 (0.03)
Midwest hospital location	0.18 (0.02)	0.19 (0.02)
South hospital location	0.14 (0.02)	0.14 (0.02)
6-99 hospital beds	-0.11 (0.03)	-0.10 (0.03)
100-399 hospital beds	-0.02 (0.02)	-0.02 (0.02)
Presence of MCU	-0.08 (0.02)	-0.07 (0.02)
Teaching hospital	0.06 (0.02)	0.06 (0.02)
Urban hospital	-0.11 (0.04)	-0.10 (0.04)
For-profit hospital	0.08 (0.03)	0.07 (0.03)
Non-profit, non-government	0.03 (0.02)	0.03 (0.02)

β is the parameter estimate. SE is the Standard Error.

References:

1. Specifications Manual for the National Hospital Quality Measures. 2008.
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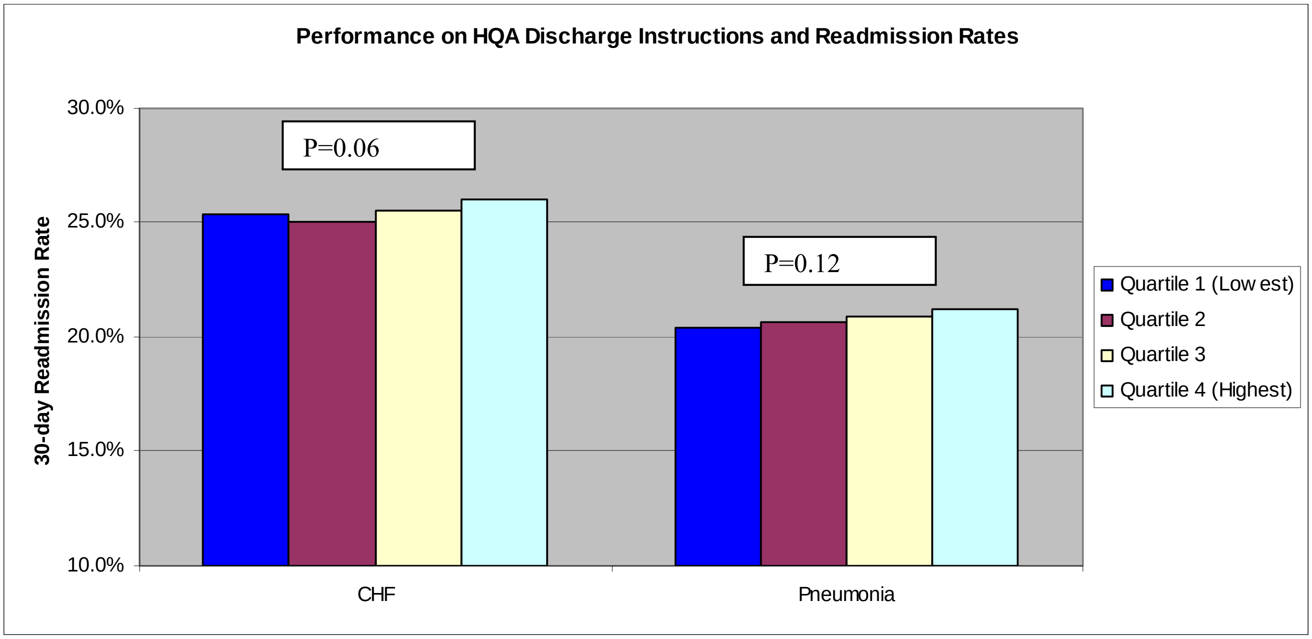
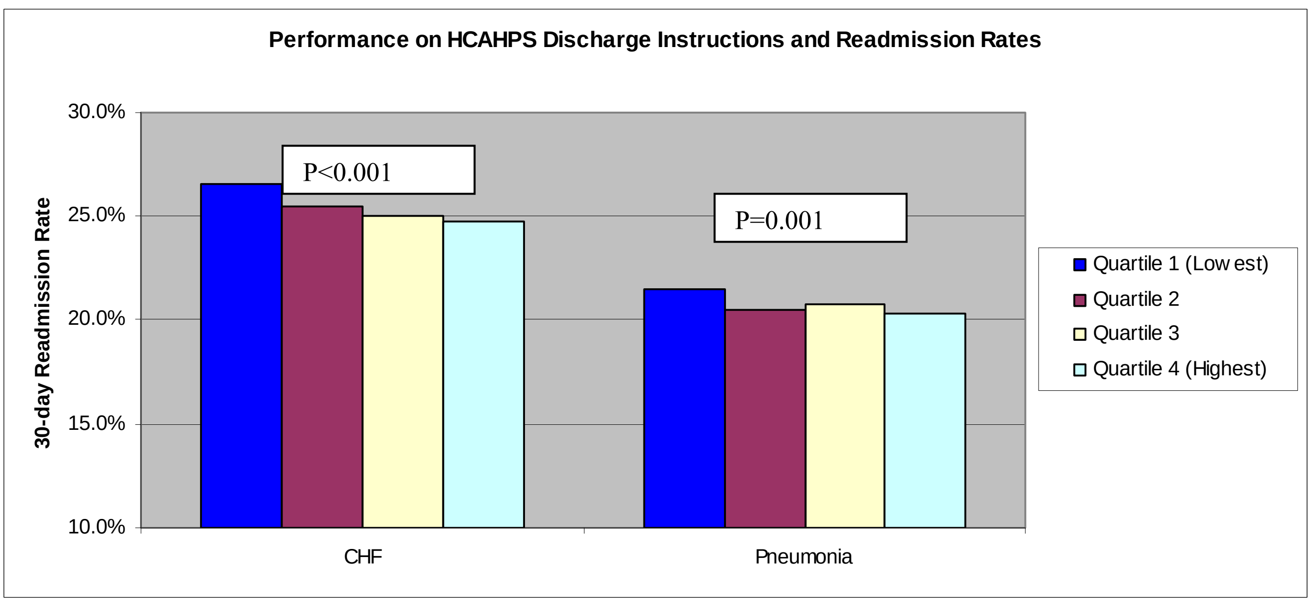
4. Southern DA, Quan H, Ghali WA. Comparison of the Elixhauser and Charlson/Deyo methods of comorbidity measurement in administrative data. Med Care. 2004 Apr;42(4):355-60.
5. Jha AK, Li Z, Orav EJ, Epstein AM. Care in U.S. hospitals--the Hospital Quality Alliance program. N Engl J Med. 2005 Jul 21;353(3):265-74.
6. Ayanian JZ, Weissman JS. Teaching hospitals and quality of care: a review of the literature. The Milbank Q. 2002;80(3):569-93, v.

Appendix Figure 1a. Performance on the chart-based discharge metric and 30-day readmission rates* for Congestive Heart Failure and Pneumonia



*Re-admission rates have been adjusted for patient-characteristics including age, sex, race, and the presence or absence of 29 comorbidities. P-values are from a test for trend.

Appendix Figure 1b. Performance on the patient-reported discharge metric and 30-day risk readmission rates* for Congestive Heart Failure and Pneumonia



*Re-admission rates have been adjusted for patient-characteristics including age, sex, race, and the presence or absence of 29 comorbidities. P-values are from a test for trend.