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Appendix

Appendix 1a: Analytic Methods

Risk factors were obtained for each encounter from emergency department or hospital claims extending 12 months prior to and including the index admission. We excluded encounters that occurred in hospitals with invalid identifiers, if the lengths of stay exceeded one year, had conflicting dates (e.g. the discharge date preceded the admission date, or multiple encounters overlapped for a unique patient), or did not have at least 90 days of post-discharge information. Minor analytic modifications were necessary to accommodate data structure differences between HCUP and CMS; comorbidity variables were derived from ICD-9-CM diagnosis codes from all hospital inpatient and emergency department encounters occurring within the previous 365 days, and we included a categorical variable for discharge year. SAS 9.4 (SAS Institute Inc., Cary, NC) was used for all data management and analysis.

Appendix 1b: Statistical Methods: Intracluster Correlation Coefficient to Estimate the Hospital Quality Signal

Although the Intra-Cluster Correlation Coefficient is routinely used in the design and analysis of cluster randomized trials, we have extended its interpretation to examine how much of the readmission risk is correlated with the hospital. Applying the same mathematical foundation, the ICC represents how much readmission variation arises from the hospital (effect of the cluster) divided by the total variation arising from the hospital plus all other drivers of readmission variation (e.g. patient factors, pre/post hospital risk, unmeasured confounding).

The estimated ICC, established for binary outcomes, is given by

$$\widehat{ICC} = \frac{\hat{\sigma}_h^2}{\hat{\sigma}_h^2 + (\pi^2/3)}$$

where $\hat{\sigma}_h^2$ is the estimated variation arising from the hospital cluster, $(\pi^2/3)$ represents the variance from a standard logistic distribution, and the constant π equals 3.14159. (1-3)

Appendix 2a: Risk variables used for clinical conditions in the acute myocardial infarction measure.

n	(%)	Risk Variables For Clinical Conditions
312,827	84.0	Coronary atherosclerosis (CC 84)
151,165	40.6	Diabetes mellitus (DM) or DM complications (CC 15-20, 119-120)
146,964	39.5	Iron deficiency or other unspecified anemias and blood disease (CC 47)
94,835	25.5	Chronic obstructive pulmonary disease (COPD) (CC 108)
86,642	23.3	Acute coronary syndrome (CC 81-82)
85,973	23.1	Valvular or rheumatic heart disease (CC 86)
83,572	22.5	Angina pectoris/old myocardial infarction (CC 83)
82,076	22.1	Congestive heart failure (CC 80)
78,076	21.0	Specified arrhythmias and other heart rhythm disorders (CC 92- 93)
71,037	19.1	Disorders of fluid/electrolyte/acid-base (CC 22-23)
62,637	16.8	Renal failure (CC 131)
58,832	15.8	Pneumonia (CC 111-113)
56,989	15.3	Vascular or circulatory disease (CC 104-106)
53,857	14.5	Dementia or other specified brain disorders (CC 49-50)
50,310	13.5	History of Percutaneous Transluminal Coronary Angioplasty (PTCA) (ICD-9 codes V45.82, 00.66, 36.06, 36.07)
50,299	13.5	Other urinary tract disorders (CC 136)
46,058	12.4	Other location of myocardial infarction (ICD-9 codes 410.20-410.62)
42,818	11.5	History of Coronary Artery Bypass Graft (CABG) surgery (ICD-9 codes V45.81, 36.10-36.16)
40,386	10.9	Anterior myocardial infarction (ICD-9 codes 410.00-410.12)
29,151	7.8	Cancer (CC 8-12)
25,785	6.9	History of infection (CC 1, 3-6)
24,828	6.7	Cerebrovascular disease (CC 97-99, 103)
16,483	4.4	Protein-calorie malnutrition (CC 21)
15,052	4.0	Asthma (CC 110)
14,556	3.9	Hemiplegia, paraplegia, paralysis, functional disability (CC 67-69, 100- 102, 177-178)

13,071	3.5	Decubitus ulcer or chronic skin ulcer (CC 148-149)
7,635	2.1	Stroke (CC 95-96)
7,248	1.9	End-stage renal disease or dialysis (CC 129-130)
5,960	1.6	Metastatic cancer or acute leukemia (CC 7)

Appendix 2b: Risk variables used for clinical conditions in the heart failure measure.

n	(%)	Risk Variables For Clinical Conditions
656,041	71.2	Coronary atherosclerosis or angina (CC 83-84)
534,310	58.0	Congestive heart failure (CC 80)
479,533	52.0	Iron deficiency or other unspecified anemias and blood disease (CC 47)
450,538	48.9	Diabetes mellitus (DM) or DM complications (CC 15-20, 119-120)
420,811	45.7	Specified arrhythmias and other heart rhythm disorders (CC 92-93)
405,707	44.0	Other gastrointestinal disorders (CC 36)
397,743	43.2	Chronic obstructive pulmonary disease (COPD) (CC 108)
360,628	39.1	Valvular or rheumatic heart disease (CC 86)
337,560	36.6	Disorders of fluid/electrolyte/acid-base (CC 22-23)
337,017	36.6	Renal failure (CC 131)
271,897	29.5	Pneumonia (CC 111-113)
248,986	27.0	Vascular or circulatory disease (CC 104-106)
190,668	20.7	History of Coronary Artery Bypass Graft (CABG) (ICD-9 codes V45.81, 36.10-36.16)
189,226	20.5	Other urinary tract disorders (CC 136)
162,881	17.7	Dementia or other specified brain disorders (CC 49-50)
145,734	15.8	Cardio-respiratory failure or shock (CC 79)
136,523	14.8	Depression (CC 58)
120,423	13.1	Acute coronary syndrome (CC 81-82)
104,631	11.4	Drug/alcohol abuse/dependence/psychosis (CC 51-53)
93,170	10.1	Peptic ulcer, hemorrhage, other specified gastrointestinal disorders (CC 34)
91,377	9.9	Cancer (CC 8-12)
90,219	9.8	Other psychiatric disorders (CC 60)
84,038	9.1	Other or unspecified heart disease (CC 94)
74,521	8.1	Decubitus ulcer or chronic skin ulcer (CC 148-149)
64,466	7.0	Protein-calorie malnutrition (CC 21)
63,000	6.8	Liver or biliary disease (CC 25-30)

57,406	6.2	Asthma (CC 110)
52,751	5.7	Hemiplegia, paraplegia, paralysis, functional disability (CC 67-69, 100- 102, 177-178)
50,329	5.5	Fibrosis of lung or other chronic lung disorders (CC 109)
43,757	4.7	Major psychiatric disorders (CC 54-56)
38,232	4.1	Nephritis (CC 132)
35,159	3.8	End-stage renal disease or dialysis (CC 129-130)
25,429	2.8	Severe hematological disorders (CC 44)
24,485	2.7	Stroke (CC 95-96)
14,194	1.5	Metastatic cancer or acute leukemia (CC 7)

Appendix 2c: Risk variables used for clinical conditions in the pneumonia measure.

n	(%)	Risk Variables For Clinical Conditions
332,722	50.1	Pneumonia (CC 111-113)
324,573	48.9	Chronic obstructive pulmonary disease (COPD) (CC 108)
307,034	46.3	Iron deficiency or other unspecified anemias and blood disease (CC 47)
304,249	45.8	Other gastrointestinal disorders (CC 36)
273,813	41.3	Coronary atherosclerosis or angina (CC 83-84)
229,983	34.6	Diabetes mellitus (DM) or DM complications (CC 15-19, 119-120)
193,844	29.2	Disorders of fluid/electrolyte/acid-base (CC 22-23)
166,167	25.0	Dementia or other specified brain disorders (CC 49-50)
161,199	24.3	Specified arrhythmias and other heart rhythm disorders (CC 92-93)
154,874	23.3	Congestive heart failure (CC 80)
130,074	19.6	Other lung disorders (CC 115)
116,726	17.6	Renal failure (CC 131)
112,807	17.0	Vascular or circulatory disease (CC 104-106)
105,748	15.9	Urinary tract infection (CC 135)
96,973	14.6	History of infection (CC 1, 3-6)
96,178	14.5	Lung, upper digestive tract, and other severe cancers (CC 8)
96,078	14.5	Other injuries (CC 162)
94,034	14.2	Other urinary tract disorders (CC 136)
87,784	13.2	Valvular or rheumatic heart disease (CC 86)
85,691	12.9	Drug/alcohol abuse/dependence/psychosis (CC 51-53)
83,202	12.5	Cardio-respiratory failure or shock (CC 79)
69,440	10.5	Protein-calorie malnutrition (CC 21)
65,571	9.9	Other psychiatric disorders (CC 60)
62,373	9.4	Fibrosis of lung or other chronic lung disorders (CC 109)
60,408	9.1	History of Coronary Artery Bypass Graft (CABG) (ICD-9 codes V45.81, 36.10-36.16)
59,102	8.9	Other major cancers (CC 9-10)

48,431	7.3	Asthma (CC 110)
43,536	6.6	Major psychiatric disorders (CC 54-56)
43,515	6.6	Decubitus ulcer or chronic skin ulcer (CC 148-149)
42,095	6.3	Septicemia/shock (CC 2)
37,205	5.6	Hemiplegia, paraplegia, paralysis, functional disability (CC 67-69, 100- 102, 177-178)
32,725	4.9	Pleural effusion/pneumothorax (CC 114)
30,183	4.5	Acute coronary syndrome (CC 81-82)
26,602	4.0	Metastatic cancer or acute leukemia (CC 7)
18,938	2.9	Severe hematological disorders (CC 44)
18,662	2.8	Vertebral fractures (CC 157)
17,105	2.6	Stroke (CC 95-96)
13,714	2.1	End-stage renal disease or dialysis (CC 129-130)

Appendix 2d: Risk variables used for clinical conditions in the hospital-wide readmission measure, for all cohorts.

n	(%)	Risk Variables For Clinical Conditions
8,639,589	55.4	Coronary atherosclerosis or angina, cerebrovascular disease (CC 81-84, 89, 98-99, 103-106)
6,547,171	42.0	Iron deficiency or other unspecified anemias and blood disease (CC 47)
5,480,581	35.1	Diabetes mellitus (DM) or DM complications (CC 15- 20, 119-120)
4,194,685	26.9	Chronic obstructive pulmonary disease (COPD) (CC 108)
3,931,251	25.2	Disorders of fluid/electrolyte/acid-base (CC 22-23)
3,648,812	23.4	Other infectious diseases and pneumonias (CC 6, 111-113)
3,629,020	23.3	Psychiatric comorbidity (CC 54-56, 58, 60)
3,492,584	22.4	Specified arrhythmias and other heart rhythm disorders (CC 92-93)
3,095,833	19.9	Congestive heart failure (CC 80)
2,671,607	17.1	Renal failure (CC 131)
1,453,945	9.3	Other cancers (CC 10-12)
1,198,910	7.7	Cardio-respiratory failure or shock (CC 79)
1,145,625	7.3	Protein-calorie malnutrition (CC 21)
969,540	6.2	Decubitus ulcer or chronic skin ulcer (CC 148-149)
828,989	5.3	Hemiplegia, paraplegia, paralysis, functional disability (CC 67-69, 100-102, 177-178)
804,062	5.2	Severe cancer (CC 8-9)
762,360	4.9	Septicemia/shock (CC 2)
754,565	4.8	Coagulation defects and other specified hematological disorders (CC 46)
673,931	4.3	Seizure disorders and convulsions (CC 74)
658,204	4.2	Rheumatoid arthritis and inflammatory connective tissue disease (CC 38)
566,351	3.6	Metastatic cancer or acute leukemia (CC 7)
565,890	3.6	Fibrosis of lung or other chronic lung disorders (CC 109)
481,899	3.1	Drug/alcohol psychosis or dependence (CC 51-52)
410,316	2.6	Pancreatic disease (CC 32)
372,946	2.4	Hip fracture/dislocation (CC 158)
346,885	2.2	Severe hematological disorders (CC 44)

318,044	2.0	Dialysis status (CC 130)
293,157	1.9	End-stage liver disease (CC 25-26)
228,683	1.5	Severe infection (CC 1, 3-5)
80,914	0.5	Respirator dependence/tracheostomy status (CC 77)
66,105	0.4	Transplants (CC 128, 174)

Appendix 3: Characteristics of hospital encounters among acute myocardial infarction, heart failure, pneumonia and combined hospital-wide readmission cohorts.

Characteristic	Acute Myocardial Infarction	Heart Failure	Pneumonia	Hospital-Wide Readmission
Race or ethnicity —%[a]				
White	73.3	68.4	72.8	71.7
Black	6.3	11.0	6.3	8.3
Hispanic	11.7	13.2	12.4	12.1
Asian or Pacific Islander	3.6	3.5	4.5	3.7
Native American	0.2	0.2	0.2	0.2
Other	3.2	2.3	1.9	2.3
Missing	1.9	1.4	1.8	1.7
Primary payer — %[a]				
Medicare[b]	89.1	90.9	90.4	89.7
Medicaid	2.5	3.0	3.2	2.7
Private insurance	6.8	4.6	5.1	6.1
Self-pay	0.6	0.5	0.5	0.5
No charge	0.1	0.1	0.1	0.1
Other	0.9	0.9	0.8	0.9
Not reported, missing	0.0	0.0	0.0	0.0
Rural-Urban Continuum Codes, 2003 —%[c]				
1 (metro)	67.2	69.4	66.5	68.9
2	21.4	19.7	20.7	20.0
3	4.7	4.6	5.5	4.8
4	4.1	3.6	3.8	3.7
5	0.3	0.4	0.7	0.5
6	1.8	1.9	2.3	1.8
7	0.3	0.2	0.4	0.3
8	0.2	0.2	0.2	0.2
9 (non-metro)	0.1	0.0	0.0	0.0
Median household income state quartile for patient ZIP Code — %				
Q1	25.3	28.1	26.0	25.4
Q2	26.6	26.0	26.7	25.9
Q3	25.5	24.8	25.4	25.5
Q4	22.6	21.1	21.9	23.3

Characteristic	Acute Myocardial Infarction	Heart Failure	Pneumonia	Hospital-Wide Readmission
Hospital Type —% [a]				
Private < 100 beds	1.1	1.9	2.4	16.9
Private ≥ 100 beds	17.6	17.7	16.0	1.2
Non-profit, rural <100 beds	0.1	1.2	2.2	2.0
Non-profit, rural ≥100 beds	1.7	2.2	2.8	2.2
Non-profit, urban <100 beds	0.6	2.1	3.5	24.2
Non-profit, urban 100-299 beds	20.6	24.5	28.2	45.6
Non-profit, urban ≥300 beds	52.2	44.9	39.8	5.8
Missing	6.1	5.5	5.1	2.1

[a] Not included in the models.

[b] Medicare Payer includes Medicare Advantage and Medicare Fee-for-Service and are not distinguished in the data.

[c] 1: Metro - Counties in metro areas of 1 million population or more;
2: Metro - Counties in metro areas of 250,000 to 1 million population;
3: Metro - Counties in metro areas of fewer than 250,000 population;
4: Non-Metro - Urban population of 20,000 or more, adjacent to a metro area;
5: Non-Metro - Urban population of 20,000 or more, not adjacent to a metro area;
6: Non-Metro - Urban population of 2,500 to 19,999, adjacent to a metro area;
7: Non-Metro - Urban population of 2,500 to 19,999, not adjacent to a metro area;
8: Non-Metro - Completely rural or less than 2,500 urban population, adjacent to a metro area;
9: Non-Metro - Completely rural or less than 2,500 urban population, not adjacent to a metro area.

Appendix 4: Readmission odds ratios (OR) for geodemographic factors at 3, 7, 30, 90 days, and 95% confidence intervals.

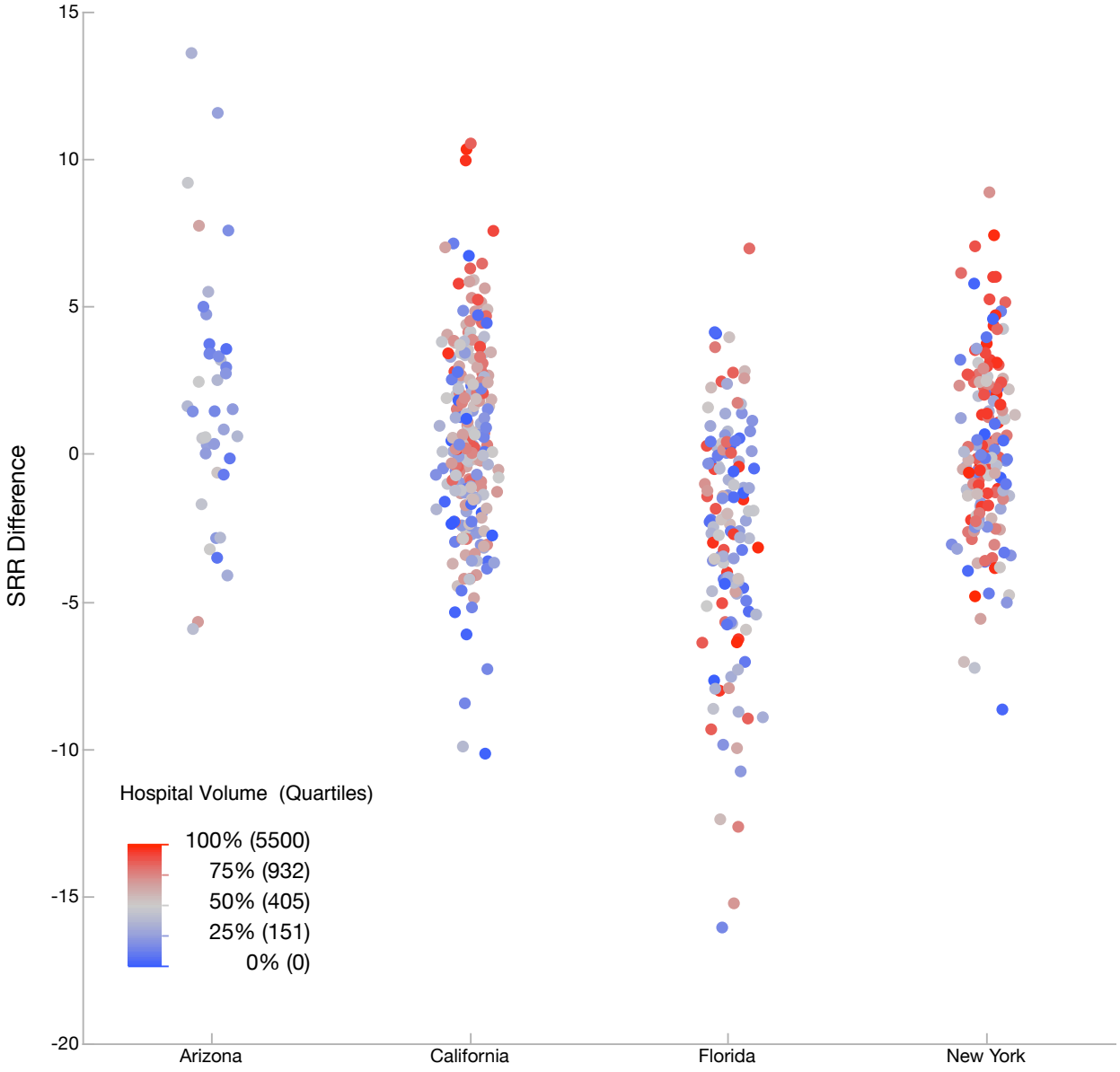
Effect	OR 3-days (95% CI)*	p value	OR 7-days (95% CI)*	p value	OR 30 days (95% CI)*	p value	OR 90-days (95% CI)*	p value
Acute myocardial infarction								
Rural urban continuum 9 vs. 1	0.88	0.430	1.00	0.981	2.34	0.002	1.85	0.001
Income lowest vs. highest	1.05	0.011	1.09	<0.001	1.11	<0.001	1.15	<0.001
State 1 vs. State 4	0.75	<0.001	0.68	<0.001	0.62	<0.001	0.58	<0.001
Heart failure								
Rural urban continuum 9 vs. 1	1.14	0.607	1.22	0.266	1.52	<0.001	2.26	<0.001
Income lowest vs. highest	1.06	<0.001	1.07	<0.001	1.09	<0.001	1.14	<0.001
State 1 vs. State 4	0.79	<0.001	0.73	<0.001	0.68	<0.001	0.6	<0.001
Pneumonia								
Rural urban continuum 9 vs. 1	1.51	0.196	1.08	0.691	1.41	0.010	1.94	<0.001
Income lowest vs. highest	1.04	0.004	1.08	<0.001	1.13	<0.001	1.19	<0.001
State 1 vs. State 4	0.83	<0.001	0.83	<0.001	0.74	<0.001	0.67	<0.001
Medicine								
Rural urban continuum 9 vs. 1	2.64	0.173	1.19	0.612	1.99	0.015	2.27	<0.001
Income lowest vs. highest	1.06	0.044	1.09	<0.001	1.13	<0.001	1.19	<0.001
State 1 vs. State 4	0.91	0.204	0.89	0.029	0.75	<0.001	0.66	<0.001
Surgery								
Rural urban continuum 9 vs. 1	1.19	0.705	1.77	0.114	1.74	0.009	2.77	<0.001
Income lowest vs. highest	1.01	0.423	1.05	<0.001	1.1	<0.001	1.15	<0.001
State 1 vs. State 4	0.78	<0.001	0.75	<0.001	0.7	<0.001	0.62	<0.001
Neurology								
Rural urban continuum 9 vs. 1	2.53	0.191	1.6	0.221	1.5	0.078	1.99	<0.001
Income lowest vs. highest	1.08	0.001	1.08	<0.001	1.09	<0.001	1.13	<0.001
State 1 vs. State 4	0.85	0.006	0.8	<0.001	0.75	<0.001	0.67	<0.001
Cardiorespiratory								
Rural urban continuum 9 vs. 1	1.10	0.610	1.02	0.899	1.46	<0.001	1.75	<0.001
Income lowest vs. highest	1.10	0.649	1.03	<0.001	1.06	<0.001	1.10	<0.001
State 1 vs. State 4	0.77	<0.001	0.71	<0.001	0.66	<0.001	0.60	<0.001
Cardiovascular								
Rural urban continuum 9 vs. 1	1.71	0.034	1.59	0.006	1.98	<0.001	2.28	<0.001
Income lowest vs. highest	1.05	<0.001	1.06	<0.001	1.1	<0.001	1.13	<0.001
State 1 vs. State 4	0.86	<0.001	0.83	<0.001	0.76	<0.001	0.69	<0.001

Appendix 5: State-level stratified Intracluster correlation coefficient estimates

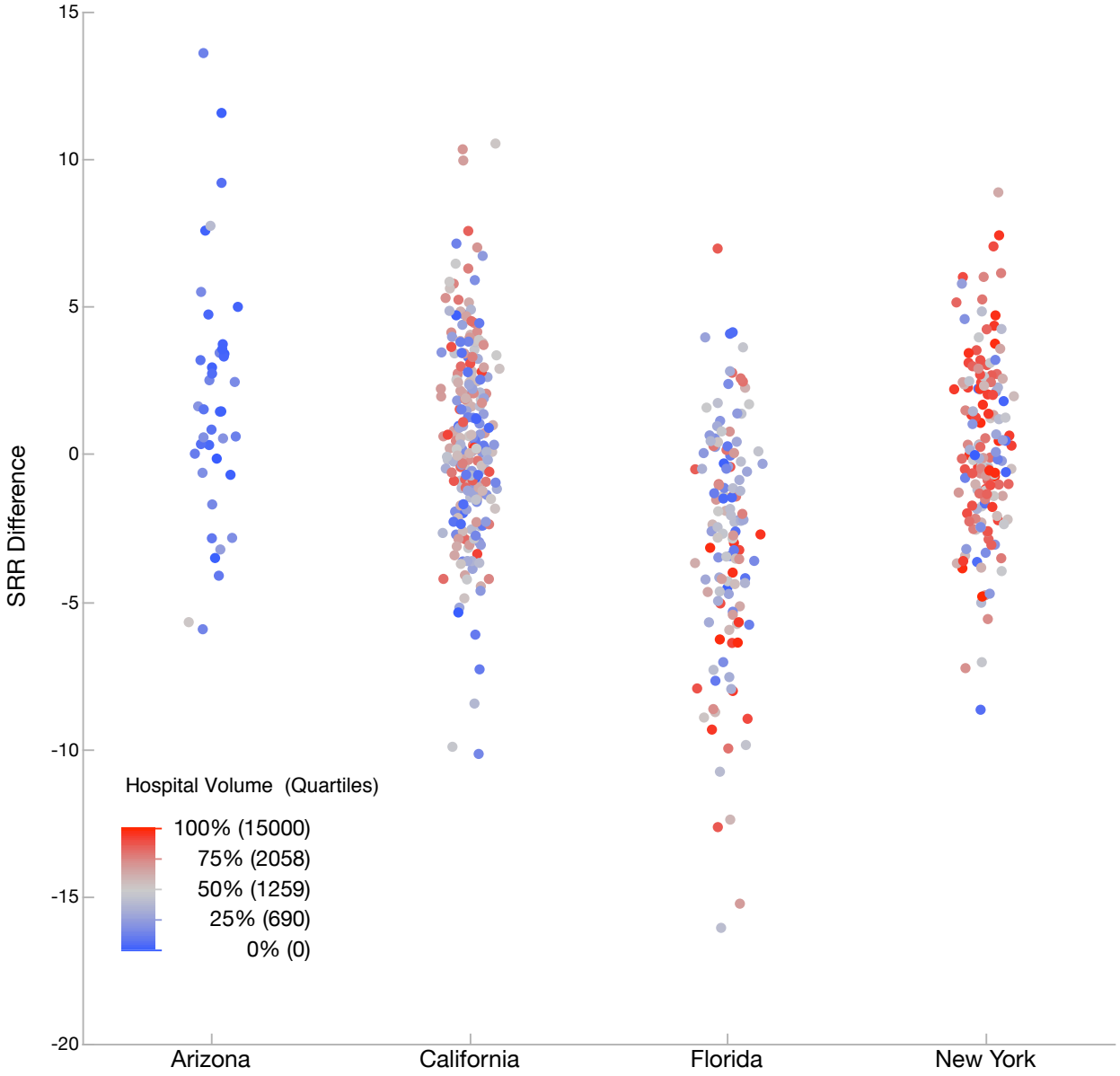
State	Acute Myocardial Infarction*	Heart Failure	Pneumonia
	Intracluster Correlation Coefficient		
Readmission Day 7			
Arizona	3.58	3.47	2.19
California	0.49	0.53	0.52
Florida	0.49	0.79	0.57
New York	0.39	0.69	0.74
Readmission Day 30			
Arizona	4.11	4.15	4.60
California	0.78	0.57	0.53
New York	0.62	0.72	0.58
Florida	0.68	0.78	0.82

Note: Readmission cohorts were stratified by state to examine between state hospital quality signal differences.

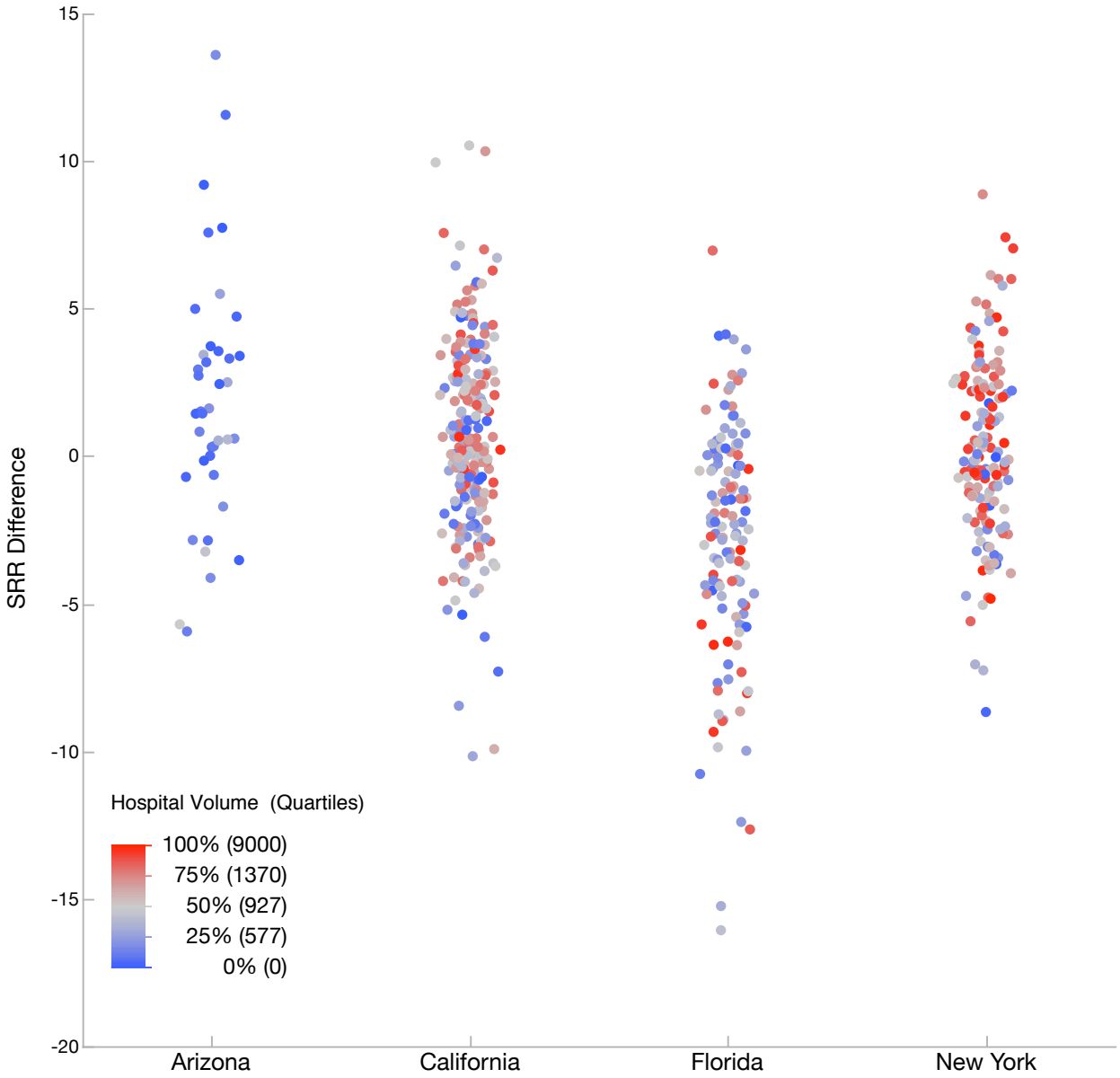
Appendix 6a: Standardized readmission ratio difference, readmission on day 7 versus 30 for acute myocardial infarction stratified by state.



Appendix 6b: Standardized readmission ratio difference, readmission on day 7 versus 30 for heart failure stratified by state.

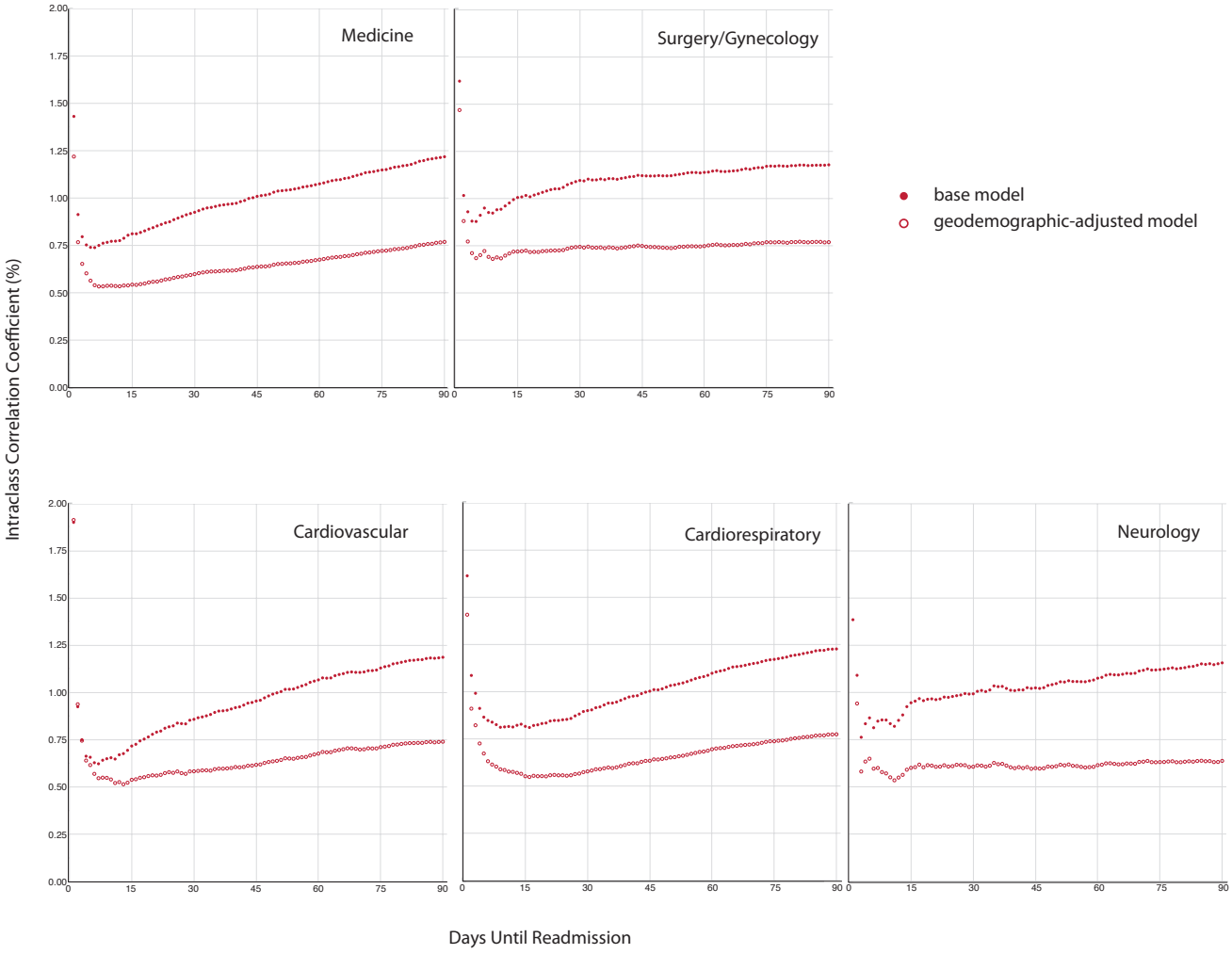


Appendix 6c: Standardized readmission ratio difference, readmission on day 7 versus 30 for pneumonia stratified by state.



Note: Hospital volume is shown in blue-red color gradient.

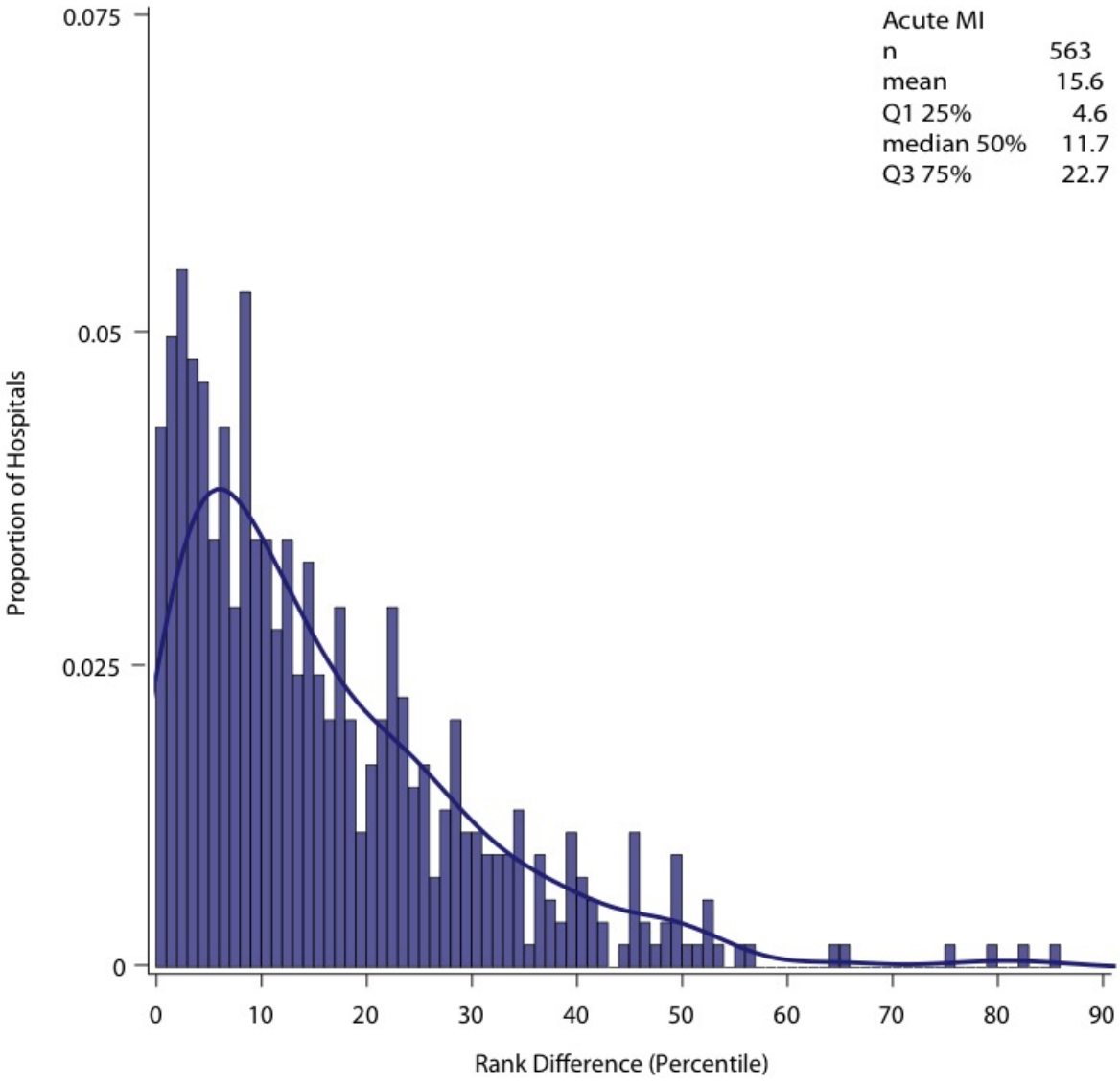
Appendix 7: Hospital-Wide intracluster correlation coefficient estimates at specific readmission intervals from 1 day through 90 days, for base and geodemographic-extended models by hospital subcategory: medicine, surgical/gynecology, cardiorespiratory, cardiovascular, and neurology.



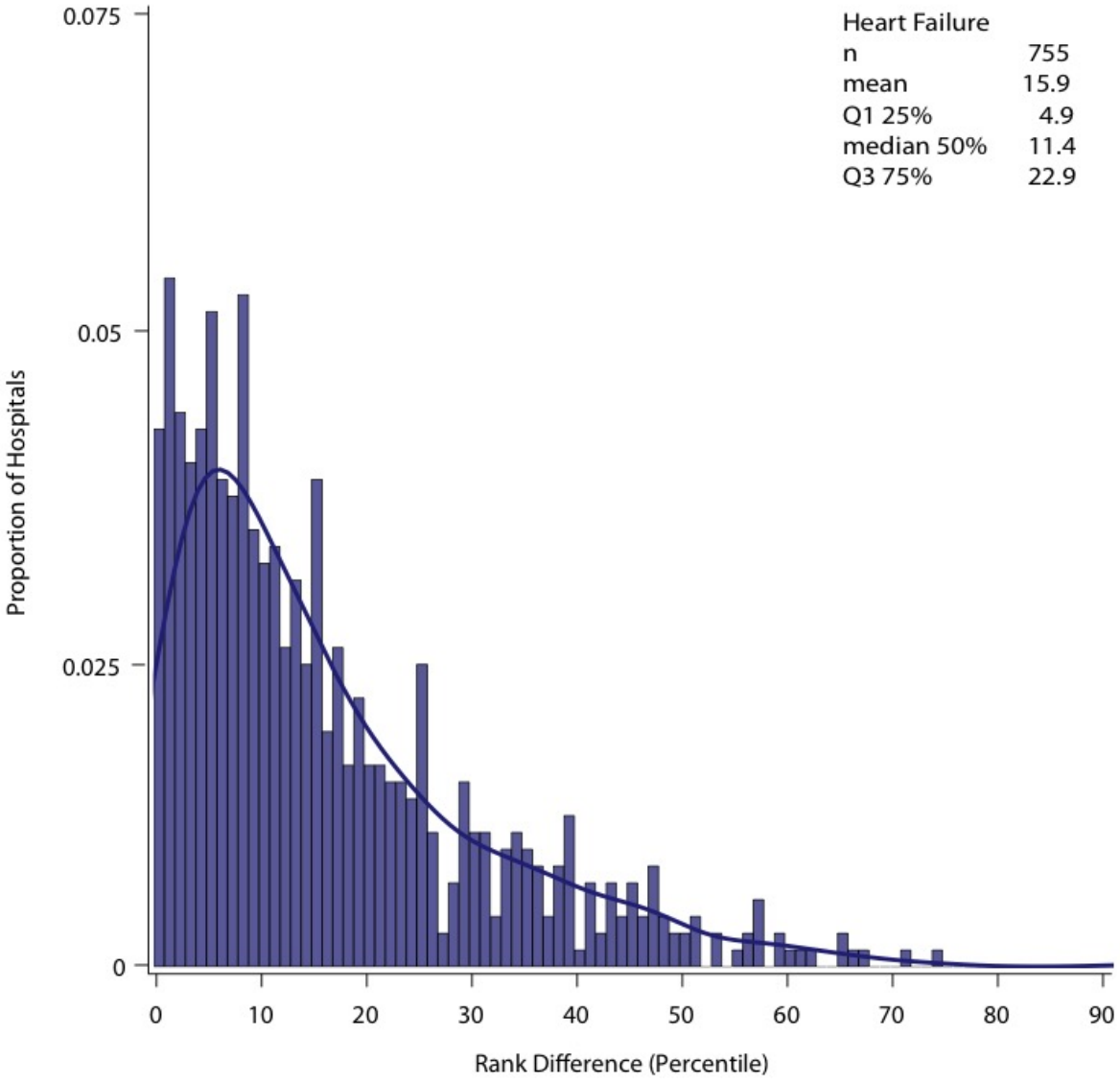
Note: Hospital-Wide intracluster correlation coefficient estimates at specific readmission intervals from 1 day through 90 days, for base and geodemographic-extended models by hospital subcategory: medicine, surgical/gynecology, cardiorespiratory, cardiovascular, and neurology.

Source: Authors' analysis of data from the Healthcare Cost and Utilization Project (HCUP), State Inpatient Database and State Emergency Department Database.

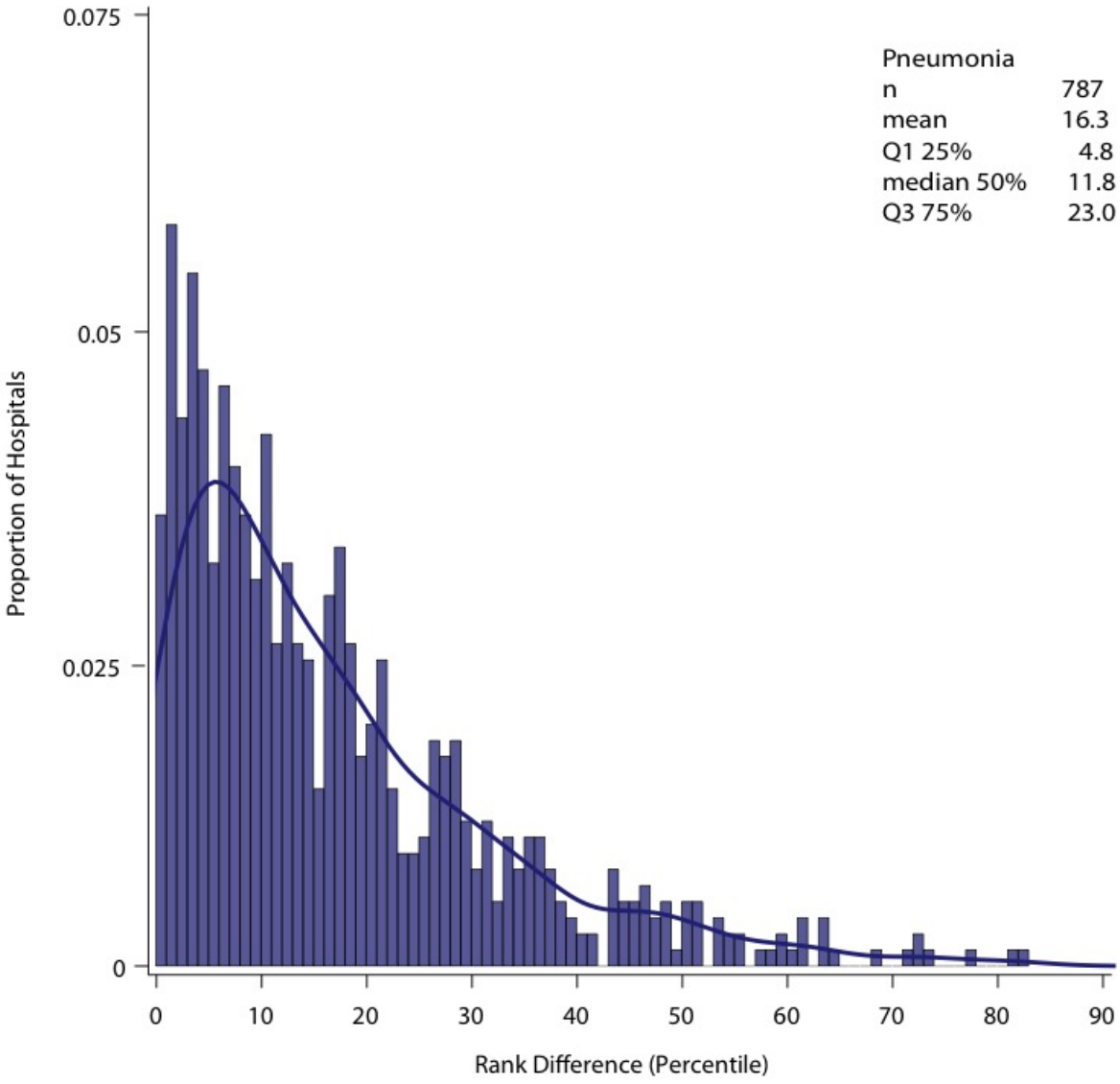
Appendix 8a: Hospital Performance Rank Change Comparing Readmission Day 7 to 30 for the acute myocardial infarction cohort.



Appendix 8b: Hospital Performance Rank Change Comparing Readmission Day 7 to 30 for the heart failure cohort.

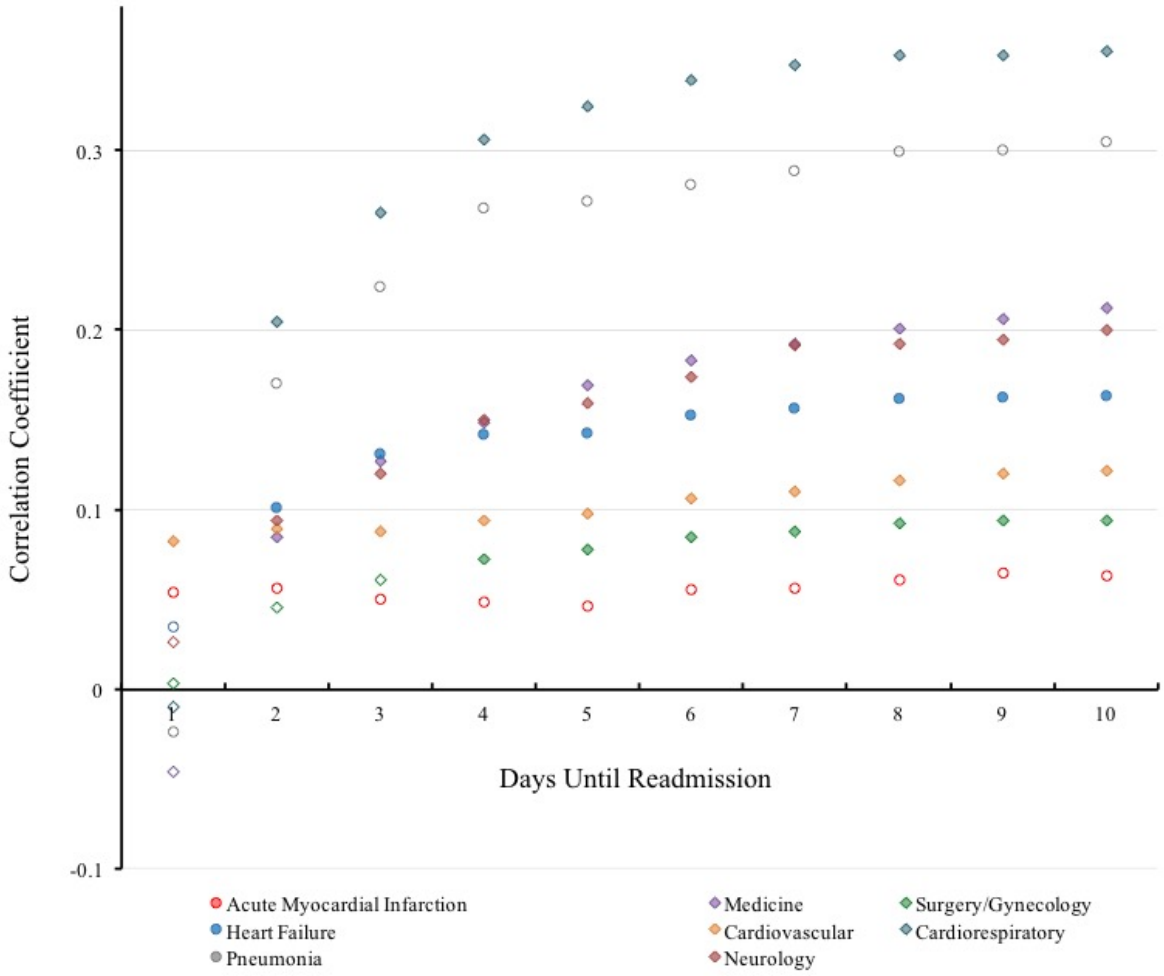


Appendix 8c: Hospital Performance Rank Change Comparing Readmission Day 7 to 30 for the pneumonia cohort.



Note: Risk standardized readmission ratios were used to calculate the performance percentile for acute myocardial infarction, heart failure and pneumonia cohorts.

Appendix 9: Pearson correlation between unadjusted hospital readmission rate and length of stay, weighted by facility volume, by readmission cohort: acute myocardial infarction, heart failure, pneumonia, medicine, surgical/gynecology, cardiorespiratory, cardiovascular, and neurology.



Note: Filled markers indicate $p<0.05$.

Appendix 10: Agreement between index hospital discharge disposition and subsequent encounter, by readmissions at post-discharge day 1-7, 30 and 1-30 (cumulative).

	Disagreement Between Hospitals		Agreement Between Hospitals			
Index Encounter (Discharge Disposition)	**Not Transferred**		**Not Transferred**		**All Readmissions in Analysis**	
Subsequent Encounter (Admission Source)	**Received Transfer In**		**Received Non-Transfer**			
Day After Discharge	**n**	**(%)**	**n**	**(%)**	**N**	**(%)**
1	3,102	2.6	115,980	97.4	119,082	0.8
2	3,245	2.2	143,993	97.8	147,238	1.0
3	3,189	2.3	134,249	97.7	137,438	0.9
4	2,957	2.3	125,693	97.7	128,650	0.8
5	2,936	2.4	118,890	97.6	121,826	0.8
6	2,887	2.5	113,771	97.5	116,658	0.8
7	2,835	2.5	109,486	97.5	112,321	0.7
30	1,167	2.6	44,340	97.4	45,507	0.3
1 to 30	63,108	2.5	2,414,302	97.5	2,477,410	16.3

Appendix Notes

1. Goldstein H, Browne W, Rasbash J. Partitioning variation in multilevel models. Understanding Statistics: Statistical Issues in Psychology, Education, and the Social Sciences. 2002;1(4):223-31.
2. Ridout MS, Demétrio CG, Firth D. Estimating intraclass correlation for binary data. Biometrics. 1999;55(1):137-48.
3. Feng Z, Grizzle JE. Correlated binomial variates: Properties of estimator of intraclass correlation and its effect on sample size calculation. Stat Med. 1992;11(12):1607-14.