Technical Appendix

<u>Risk-Adjusted Readmission Rates and Risk-Adjusted Mortality Rates:</u>
We examined every hospitalization with the primary discharge diagnosis of heart failure (HF) (ICD-9 codes 398.91, 404.x1, 404.x3, 428.0 to 428.9) in which the patient was discharged prior to December 1 (to ensure that all patients had at least 30 days to be readmitted). We then analyzed all-cause readmissions within 30 days of discharge and all-cause mortality within 30 days of admission using the Elixhauser adjustment scheme, where the likelihood of readmission or death was adjusted for patient characteristics including age, gender, race, and the presence or absence of up to 29 co-morbidities. The Elixhauser adjustment was developed for mortality and is widely accepted for its good predictive validity.(16-18)

However, to evaluate its validity for readmissions, we proceeded with additional analysis. We presumed that age and the presence of a wide range of comorbid conditions are also likely to be factors associated with a higher risk of readmission. We built our risk-adjusted models for readmission rates for HF patients in a logistic regression model as follows:

$$y = \alpha + \beta_1 \text{ age} + \beta_2 \text{ gender} + \beta_3 \text{ race} + \beta_4 \text{ Comorb1} + \ldots \ldots \beta_{32} \text{ e}_i$$

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 Table 1. We calculated rates of readmission for each hospital.

We found that the Elixhauser scheme had very good predictive ability for readmission: 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 HF 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.

There is no consistent and validated alternative approach to risk-adjustment of readmissions(40) although Krumholz and colleagues did develop a Bayesian approach that is currently being used for public reporting.(3) However, it dramatically shrinks variation, especially for smaller hospitals, leading to much greater homogeneity among all hospitals.(3) Our approach, which has a C-statistic of 0.60, and yet, retains much of the natural variation that exists within the data, compares favorably with the Krumholz approach, which has a c-statistic of 0.61.

Appendix Table 1: Description of 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 Disease	-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.

Appendix Table 2: The relationship between case volume and processes and outcomes of care, stratified by volume group

Appendix Table 2a: The relationship between case volume and processes of care for heart failure, stratified by volume group (spline knots at 100 and 400 discharges in 2006-2007)

Volume group	Unadjusted analysis				Adjusted for hospital characteristics				Adjusted for hospital characteristics, hospital size			
	Change per 10 pt increase in volume	P	Mean	P	Change per 10 pt increase in volume	P	Mean	P	Change per 10 pt increase in volume	P	Mean	P
Overall Score												
Low	1.27 (0.90, 1.63)	<0.001	75.9	<0.001	1.13 (0.78, 1.49)	<0.001	78.7	<0.001	1.13 (0.77, 1.49)	<0.001	78.9	<0.001
Medium	0.30 (0.25, 0.34)	<0.001	85.1	<0.001	0.17 (0.13, 0.22)	<0.001	85.5	0.007	0.16 (0.11, 0.21)	<0.001	85.6	0.09
High	-0.02 (-0.04, 0.004)	0.11	89.1	Ref	-0.03 (-0.05, -0.008)	0.007	86.9	Ref	-0.04 (-0.07, -0.02)	0.001	86.6	Ref
ACE inhibitor or ARB for patients with left ventricular systolic dysfunction												
Low	-0.68 (-1.13, -0.23)	0.003	91.1	0.27	-0.39 (-0.84, 0.05)	0.08	90.6	0.31	-0.39 (-0.83, 0.05)	0.09	90.6	0.34
Medium	0.05 (0.003, 0.09)	0.04	88.9	0.001	0.02 (-0.03, 0.06)	0.45	89.3	0.49	0.01 (-0.04, 0.06)	0.68	89.3	0.50
High	0.002 (-0.01, 0.02)	0.77	90.1	Ref	-0.01 (-0.02, 0.001)	0.08	89.6	Ref	-0.02 (-0.04, -0.002)	0.03	89.6	Ref
Assessment of left ventricular function												
Low	1.14 (0.78, 1.49)	<0.001	81.8	<0.001	1.10 (0.76, 1.44)	<0.001	85.1	<0.001	1.10 (0.76, 1.44)	<0.001	85.5	<0.001
Medium	0.34 (0.30, 0.38)	<0.001	91.3	<0.001	0.19 (0.14, 0.23)	<0.001	91.8	<0.001	0.16 (0.12, 0.21)	<0.001	92.0	0.03
High	-0.004 (-0.02, 0.02)	0.70	96.3	Ref	-0.01 (-0.03, 0.007)	0.21	93.8	Ref	-0.03 (-0.06, -0.007)	0.01	93.2	Ref
Discharge instructions												
Low	1.11 (0.41, 1.81)	0.002	65.8	<0.001	0.87 (0.16, 1.58)	0.02	68.1	<0.001	0.87 (0.16, 1.58)	0.02	68.0	<0.001
Medium	0.27 (0.20, 0.33)	<0.001	75.1	<0.001	0.19 (0.11, 0.27)	<0.001	75.5	0.20	0.19 (0.11, 0.27)	<0.001	75.4	0.17
High	-0.04 (-0.07, -0.003)	0.03	78.0	Ref	-0.05 (-0.09, -0.01)	0.004	76.6	Ref	-0.05 (-0.09, -0.01)	0.01	76.7	Ref
Smoking cessation counseling												
Low	0.52 (0.05, 0.99)	0.03	89.9	<0.001	0.42 (-0.05, 0.89)	0.08	91.2	<0.001	0.41 (-0.006, 0.88)	0.09	91.4	<0.001
Medium	0.13 (0.08, 0.18)	<0.001	95.5	<0.001	0.11 (0.05, 0.16)	<0.001	95.6	0.03	0.10 (0.05, 0.16)	<0.001	95.9	0.09
High	0.003 (-0.01, 0.02)	0.64	97.0	Ref	-0.002 (-0.02, 0.01)	0.82	96.7	Ref	-0.007 (-0.02, 0.01)	0.44	96.6	Ref

ACE=angiotensin converting enzyme; ARB=angiotensin receptor blocker. The adjusted model accounts for the presence of a cardiac intensive care unit, hospital ownership, teaching status, hospital system membership, proportion of patients with Medicare in the overall hospital population, proportion of patients with Medicaid in the overall hospital population, urban location, and region).

Table 2b: The relationship between case volume and outcomes and costs of care for heart failure, stratified by volume group (spline knots at 100 and 400 discharges in 2006-2007)

Volume group	Unadjusted analysis				Adjusted for hospital characteristics				Adjusted for hospital characteristics, hospital size			
	Change per 10 pt increase in volume*	P	Mean	P	Change per 10 pt increase in volume*	P	Mean	P	Change per 10 pt increase in volume*	P	Mean	P
30-day mortality												
Low	-0.01 (-0.02, -0.002)	0.01	10.9%	<0.001	-0.01 (-0.02, -0.002)	0.01	10.6%	<0.001	-0.01 (-0.02, -0.002)	0.02	10.5%	<0.001
Medium	-0.007 (-0.008, -0.006)	<0.001	9.6%	<0.001	-0.006 (-0.008, -0.005)	<0.001	9.5%	<0.001	-0.006 (-0.008, -0.005)	<0.001	9.4%	<0.001
High	-0.0007 (-0.001, -0.0003)	<0.001	8.5%	Ref	-0.0006 (-0.0009, -0.0002)	0.002	8.6%	Ref	-0.0007 (-0.001, -0.0002)	0.003	8.6%	Ref
30-day readmission												
Low	-0.02 (-0.03, -0.01)	<0.001	28.9%	<0.001	-0.01 (-0.02, -0.004)	0.002	26.7%	0.02	-0.01 (-0.02, -0.005)	0.002	26.6%	0.06
Medium	-0.003 (-0.004, -0.002)	<0.001	26.3%	<0.001	-0.0002 (-0.001, 0.001)	0.78	25.9%	0.76	0.00 (-0.001, 0.001)	0.93	25.8%	0.81
High	0.0002 (-0.0001, 0.0004)	0.27	25.5%	Ref	-0.00 (-0.0004, 0.0003)	0.67	25.8%	Ref	0.0001 (-0.0003, 0.0005)	0.60	25.8%	Ref
Costs per discharge												
Low	$3.61 (-67.72, 74.93)	0.92	$7,083	<0.001	$37.04 (-35.27, 109.36)	0.32	$7,162	<0.001	$33.93 (-38.35, 106.22)	0.36	$7,476	<0.001
Medium	$32.81 (25.93, 39.69)	<0.001	$7,448	<0.001	$28.69 (21.60, 35.79)	<0.001	$7,587	<0.001	$22.75 (15.25, 30.26)	<0.001	$7,811	<0.001
High	$10.36 (6.98, 13.73)	<0.001	$8,379	Ref	$8.62 (5.24, 12.01)	<0.001	$8,316	Ref	$3.22 (-1.34, 7.77)	0.17	$8,264	Ref

*For 30-day mortality and readmissions, change represents the change in the log odds of mortality (or readmissions) per 10 patient increase in case volume. For costs per discharge, change represents the change in dollars per discharge, per 10 patient increase in case volume. Adjusted analyses include the presence of a cardiac intensive care unit, hospital ownership, teaching status, hospital system membership, proportion of

patients with Medicare in the overall hospital population, proportion of patients with Medicaid in the overall hospital population, urban location, and region.

Appendix Table 3: The relationship between case volume and processes and outcomes of care, stratified by volume group

Appendix Table 3a: The relationship between case volume and processes of care for heart failure, stratified by volume group (spline knots at 200 and 400 discharges in 2006-2007)

Volume group	N hospitals	Unadjusted analysis				Adjusted for hospital characteristics, hospital size			
		Change per 10 pt increase in volume	P	Mean	P	Change per 10 pt increase in volume	P	Mean	P
Overall Score									
Low	1,388	0.75 (0.64, 0.87)	<0.001	80.2	<0.001	0.57 (0.45, 0.68)	<0.001	82.4	<0.001
Medium	964	0.13 (0.06, 0.20)	<0.001	87.0	<0.001	0.02 (-0.05, 0.10)	0.50	86.6	0.90
High	991	-0.00 (-0.02, 0.02)	0.84	89.1	Ref	-0.03 (-0.06, 0.00)	0.02	86.6	Ref
ACE inhibitor or ARB for patients with left ventricular systolic dysfunction									
Low	378	-0.19 (-0.33, -0.06)	0.005	89.3	0.12	-0.12 (-0.26, 0.01)	0.08	89.5	0.79
Medium	866	0.08 (0.02, 0.14)	0.004	89.0	0.004	0.03 (-0.03, 0.09)	0.33	89.4	0.52
High	989	-0.00 (-0.02, 0.02)	0.98	90.1	Ref	-0.02 (-0.04, 0.00)	0.02	89.6	Ref
Assessment of left ventricular function									
Low	1,388	0.80 (0.69, 0.91)	<0.001	86.1	<0.001	0.58 (0.47, 0.68)	<0.001	88.8	<0.001
Medium	964	0.16 (0.09, 0.22)	<0.001	93.6	<0.001	0.02 (-0.05, 0.09)	0.54	92.9	0.64
High	991	0.01 (-0.00, 0.03)	0.23	96.3	Ref	-0.02 (-0.04, 0.00)	0.11	93.2	Ref
Discharge instructions									
Low	1,161	0.69 (0.49, 0.89)	<0.001	70.9	<0.001	0.55 (0.34, 0.75)	<0.001	72.2	<0.001
Medium	964	0.12 (0.00, 0.23)	0.04	76.6	0.13	0.06 (-0.06, 0.18)	0.31	76.5	0.75
High	991	-0.02 (-0.06, 0.01)	0.17	78.0	Ref	-0.04 (-0.08, -0.00)	0.06	76.8	Ref
Smoking cessation counseling									
Low	168	0.33 (0.18, 0.48)	<0.001	92.3	<0.001	0.27 (0.12, 0.42)	<0.001	93.3	<0.001

Medium	510	0.10 (0.03, 0.15)	0.003	95.8	0.004	0.07 (0.00, 0.13)	0.04	96.2	0.29
High	889	0.01 (-0.01, 0.02)	0.45	97.0	Ref	-0.00 (-0.02, 0.01)	0.58	96.6	Ref

ACE=angiotensin converting enzyme; ARB=angiotensin receptor blocker. The adjusted model accounts for the presence of a cardiac intensive care unit, hospital ownership, teaching status, hospital system membership, proportion of patients with Medicare in the overall hospital population, proportion of patients with Medicaid in the overall hospital population, urban location, and region).

Appendix Table 3b: The relationship between case volume and outcomes and costs of care for heart failure, stratified by volume group (spline knots at 200 and 400 discharges in 2006-2007)

Volume group	Number of patients	Number of hospitals	Unadjusted analysis				Adjusted for hospital characteristics, hospital size			
			Change per 10 pt increase in volume*	P	Mean	P	Change per 10 pt increase in volume*	P	Mean	P
30-day mortality										
Low	176,985	2,129	-0.009 (-0.012, -0.007)	<0.001	10.5%	<0.001	-0.009 (-0.01, -0.006)	<0.001	10.2%	<0.001
Medium	248,251	970	-0.006 (-0.007, -0.004)	<0.001	9.3%	<0.001	-0.006 (-0.007, -0.004)	<0.001	9.2%	<0.001
High	604,265	992	-0.0008 (-0.001, -0.0004)	<0.001	8.5%	Ref	-0.0008 (-0.001, -0.0003)	0.001	8.6%	Ref
30-day readmission										
Low	146,671	2,133	-0.009 (-0.01, -0.006)	<0.001	27.7%	<0.001	-0.003 (-0.006, 0.0005)	0.10	25.9%	0.76
Medium	214,024	970	-0.003 (-0.004, -0.0009)	0.002	26.0%	<0.001	0.00 (-0.002, 0.002)	0.92	25.8%	0.88
High	545,405	992	0.0001 (-0.0002, 0.0004)	0.40	25.5%	Ref	0.0001 (-0.0003, 0.0005)	0.59	25.8%	Ref
Costs per discharge										
Low	125,300	1,181	$21.78 (1.92, 41.61)	0.03	$7,189	<0.001	$24.52 (4.24, 44.80)	0.02	$7,609	<0.001
Medium	253,205	956	$35.76 (24.94, 46.59)	<0.001	$7,579	<0.001	$22.87 (11.90, 33.82)	<0.001	$7,882	<0.001
High	621,913	987	$10.13 (6.67, 13.59)	<0.001	$8,382	Ref	$3.19 (-1.44, 7.81)	0.18	$8,268	Ref

*For 30-day mortality and readmissions, change represents the change in the log odds of mortality (or readmissions) per 10 patient increase in case volume. For costs per discharge, change represents the change in dollars per discharge, per 10 patient increase in case volume. Adjusted analyses include the presence of a cardiac intensive care unit, hospital ownership, teaching status, hospital system membership, proportion of patients with Medicare in the overall hospital population, proportion of patients with Medicaid in the overall hospital population, urban location, and region.

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