Factors associated with differential readmission diagnoses following acute exacerbations of COPD

Online Data Supplement

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Supplementary Methods:

Database Construction

Data from 2010 to 2016 from Nationwide Readmissions Database (NRD) were obtained and combined to form a pooled dataset for the analysis [1]. The NRD is maintained by the Agency for Healthcare Research and Quality's Healthcare Cost and Utilization Project, and aggregates data from the State Inpatient Databases from participating states [2]. The included states are nationally distributed across all regions but do vary from year to year. The NRD includes linkage numbers within a given year that can be used to track an individual patient across multiple hospitals in order to facilitate readmission analyses. The limitation, however, is that these numbers are only valid within each given year, and do not translate across state lines. As such, the data is constructed with a pooled, multiple cross-sectional approach rather than truly longitudinal. Only inpatient hospital discharges from acute care hospitals are included in the database.

Detailed Inclusion and Exclusion Criteria

The aggregated NRD contains approximately 105 million observations from January 2010 to December 2016. We used the HRRP methodology reports as a template to structure inclusion and exclusion criteria, as outlined in the main text. Specific ICD-9 and ICD-10 codes used to define COPD hospitalizations follow in Appendix Tables 1 and 2 [3,4]. We adapted the HRRP criteria to also exclude those who underwent lung transplantation, recognizing that this population is fundamentally different than the general COPD population. We otherwise included those aged 40 and older discharged alive and not against medical advice as outlined in the main body. To

qualify as a new qualifying index admission, at least 30 days must have elapsed since the most recent hospitalization (i.e., HRRP does not count cascading readmissions as new events until a period of at least 30 days has elapsed) [3,4]. As such, we excluded those admitted in January, given we could not be assured they were not actually readmissions from the previous December, and because of database limitations in tracking patients across state lines [2], admissions where a patient was not a resident of the state of hospitalization were excluded to minimize loss to follow up.

Readmission Specifications

A readmission was defined by return to hospital for any reason within 30 days of an eligible discharge. The HRRP makes exceptions for planned (e.g., organ transplantation) and potentially planned readmissions (e.g., elective surgeries). Appendix Figure 11 outlines a flow diagram adapted from HRRP documentation about how these determinations are made. The exhaustive list of included diagnosis codes can be found in the HRRP documentation [3,4]. In our particular analysis, we further divided the readmitted patients into two sub-groups, those readmitted for what would have qualified as a COPD hospitalization under HRRP guidelines (as above) and those readmitted for all other reasons.

Key Variable Specifications

We used comorbidity as our primary predictor in our models, operationalized by the Elixhauser comorbidity index's most recent revision, which includes weighting for readmissions [5]. We modified a pre-existing Stata macro [6] to tabulate comorbidities from the ICD and DRG codes found in the database, using SAS code developed by AHRQ [7]. Within hospitals, we tabulated volume of all-cause and COPD-specific hospitalizations.

As a proxy for safety-net hospitals, we tabulated the proportion of within-hospital annual patient-days paid by Medicaid. Regarding payer coding, the NRD codes those with both Medicare and secondary insurance (whether dual-eligible Medicaid, or private plans like Medicare Advantage) as Medicare, and those with Medicaid and private insurance (managed Medicaid) as Medicaid [2]. Variables otherwise came pre-supplied in the database and details can be found in the database documentation [2].

Survey Weights

The NRD comes with pre-supplied sample weights to approximate a nationally representative population. Complete details on how the weights were derived are found in the database documentation, but to summarize, inverse probability weights were calculated using data from the American Hospital Association surveys to form strata on hospital types and patient characteristics (binned age groups and sex) [2]. The weight was applied during our analyses to ensure that the sample provided nationally representative estimates.

Modeling

We fit a mixed-effects multinomial logistic regression model to estimate the beta coefficients on a log odds scale for the variables of interest on multiple categorial outcomes, an extension of logistic regression where more than two outcomes are allowed. In our particular modeling approach, we had three outcomes, those not readmitted (reference), those readmitted within 30 days for a return COPD diagnosis (as defined above), and those readmitted within 30 days for any other reason. Because of the clustered nature of the data, we used random intercepts for hospital clusters.

Generalized structural equation modeling was used to construct this regression model, which does not have a prespecified command for its execution in Stata version 15.1.

In sensitivity analyses, we used a Cox proportional hazards model, incorporating time to readmission into the model, but reducing to only the two readmission outcomes, as are the limitations for this modeling technique. In this model, the beta coefficient represents the odds of readmission for non-COPD diagnoses when compared to odds of readmission for a return COPD diagnosis. Because this model did not provide significantly different proportional effect sizes or directions compared to the multinomial model, we only included the multinomial model in the main results, though the Cox results can be found below in Appendix Table 10.

We also evaluated the sensitivity of using the HRRP ICD code classification to separate into readmissions for COPD versus readmissions for other conditions by liberalizing our outcomes into readmissions for respiratory condition DRGs versus readmissions for other DRGs. In our data, DRG versions 27 through 34 were represented, and we confirmed that the range of respiratory DRGs (163 through 208) was consistent across all of the versions included in our data. We chose the more restrictive HRRP definition in the end due to consistency with the HRRP definition, recognizing that the HRRP's objective is to improve quality of care in penalized conditions, in this case, COPD.

Appendix Table 1: ICD-9 Diagnostic Codes for COPD for admissions prior to 10/1/2015

| Code	Description
491.21	Obstructive chronic bronchitis; With (acute) exacerbation; acute exacerbation of COPD, decompensated COPD, decompensated COPD with exacerbation
491.22	Obstructive chronic bronchitis; with acute bronchitis
491.8	Other chronic bronchitis. Chronic: tracheitis, tracheobronchitis.
491.9	Unspecified chronic bronchitis
492.8	Other emphysema; emphysema (lung or pulmonary): NOS, centriacinar, centrilobular, obstructive, panacinar, panlobular, unilateral, vesicular. MacLeod's syndrome; Swyer-James syndrome; unilateral hyperlucent lung
493.20	Chronic obstructive asthma; asthma with COPD, chronic asthmatic bronchitis, unspecified
493.21	Chronic obstructive asthma; asthma with COPD, chronic asthmatic bronchitis, with status asthmaticus
493.22	Chronic obstructive asthma; asthma with COPD, chronic asthmatic bronchitis, with (acute) exacerbation
496	Chronic: nonspecific lung disease, obstructive lung disease, obstructive pulmonary disease (COPD) NOS
518.81*	Other diseases of lung; acute respiratory failure; respiratory failure NOS
518.82*	Other diseases of lung; acute respiratory failure; other pulmonary insufficiency, acute respiratory distress
518.84*	Other diseases of lung; acute respiratory failure; acute & chronic respiratory failure
799.1*	Other ill-defined & unknown causes of morbidity & mortality; respiratory arrest, cardiorespiratory failure

Principal diagnosis when combined with secondary diagnosis of AECOPD (491.21, 491.22, 493.21, or 493.22). Excluded if concomitant diagnosis of lung or heart/lung transplantation (procedure codes 33.50, 33.51, 33.52, 33.6, or diagnosis code V42.6). Adapted from HRRP methodology report [3].

Appendix Table 2: ICD-10 Diagnostic Codes for COPD for admissions on or after 10/1/2015

Code	Description
J41.8	Mixed simple and mucopurulent chronic bronchitis
J42	Unspecified chronic bronchitis
J43.0	Unilateral pulmonary emphysema [MacLeod's syndrome]
J43.1	Panlobular emphysema
J43.2	Centrilobular emphysema
J43.8	Other emphysema
J43.9	Emphysema, unspecified
J44.0	Chronic obstructive pulmonary disease with acute lower respiratory infection
J44.1	Chronic obstructive pulmonary disease with (acute) exacerbation
J44.9	Chronic obstructive pulmonary disease, unspecified
J96.00*	Acute respiratory failure, unspecified whether hypoxia or hypercapnia
J96.01*	Acute respiratory failure with hypoxia
J96.02*	Acute respiratory failure with hypercapnia
J96.20*	Acute and chronic respiratory failure, unspecified whether with hypoxia or hypercapnia
J96.21*	Acute and chronic respiratory failure with hypoxia
J96.22*	Acute and chronic respiratory failure with hypercapnia
J96.90*	Respiratory failure, unspecified, unspecified whether with hypoxia or hypercapnia
J96.91*	Respiratory failure, unspecified with hypoxia
J96.92*	Respiratory failure, unspecified with hypercapnia
R09.2*	Respiratory arrest

Principal diagnosis when combined with secondary diagnosis of AECOPD (J44.0 or J44.1).
Excluded if concomitant diagnosis of lung or heart/lung transplantation (procedure codes 0BYC0Z0, 0BYC0Z1, 0BYC0Z2, 0BYD0Z0, 0BYZD0Z1, 0BYD0Z2, 0BYZF0Z0, 0BYZF0Z1, 0BYF0Z2, 0BYG0Z0, 0BYG0Z1, 0BYG0Z2, 0BYH0Z0, 0BYH0Z1, 0BYH0Z2, 0BYJ0Z0, 0BYJ0Z1, 0BYJOZ2, 0BYK0Z0, 0BYK0Z1, 0BYK0Z2, 0BYL0Z0, 0BYL0Z1, 0BYL0Z2, 0BYM0Z0, 0BYM0Z1, 0BYM0Z2 or diagnosis codes Z94.2 or Z94.3). Adapted from HRRP methodology report [4].
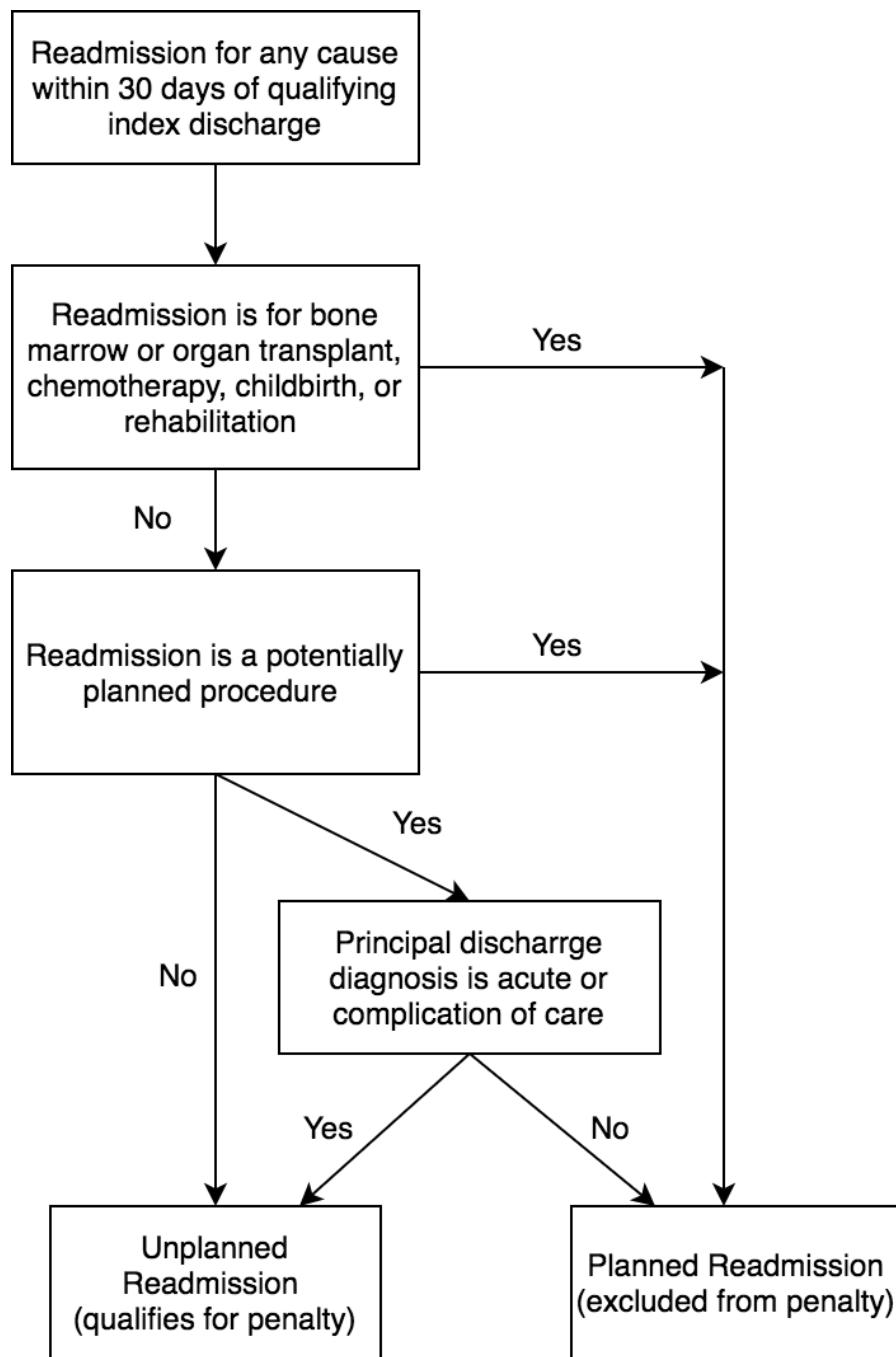
Appendix Figure 1: Published HRRP schema for excluding planned readmissions from the analysis. Figure adapted from Yale New Haven HRRP Methodology Reports, where diagnosis and procedure codes for exceptions can be found [3,4]

Appendix Table 3: Comorbidity characteristics of the aggregated cohort, comparing COPD and Non-COPD related readmissions to non-readmitted patients in index stays.

	Not Readmitted N=1,375,099	Non-COPD Readmitted N=159,675	COPD Readmitted N=128,209	*P*
Elixhauser Readmission Index, *Mean ± SD*	16.3 ± 14.7	22.8 ± 16.4	17.8 ± 14.9	<.001
Elixhauser Domain Count, *Mean ± SD*	3.92 ± 1.81	4.62 ± 1.93	4.05 ± 1.84	<.001
Elixhauser Component Comorbidities, %				
Congestive heart failure	25.4%	38.6%	28.3%	<.001
Valvular heart disease	6.2%	9.1%	5.6%	<.001
Pulmonary circulation disorders	7.6%	10.4%	9.0%	<.001
Peripheral vascular disease	7.7%	10.4%	7.6%	<.001
Hypertension (complicated + uncomplicated)	54.5%	50.0%	54.9%	<.001
Paralysis	1.2%	1.9%	1.1%	<.001
Other neurologic disorders	8.3%	10.5%	8.9%	<.001
Chronic pulmonary disease	100.0%	100.0%	100.0%	---
Diabetes mellitus (uncomplicated)	25.8%	29.2%	27.4%	<.001
Diabetes mellitus (complicated)	5.7%	8.4%	5.9%	<.001
Hypothyroidism	13.6%	15.3%	12.5%	<.001
Renal failure	12.3%	21.5%	11.8%	<.001
Liver disease	2.3%	3.2%	2.4%	<.001
Peptic ulcer disease	0.1%	0.2%	0.1%	0.062
HIV/AIDS	0.2%	0.3%	0.3%	<.001
Lymphoma	0.5%	0.8%	0.5%	<.001
Metastatic cancer	1.0%	2.2%	1.0%	<.001
Solid tumor without metastasis	3.1%	5.5%	3.6%	<.001
RA/collagen vascular disorders	3.3%	3.9%	3.0%	<.001
Coagulopathy	3.1%	4.5%	3.0%	<.001
Obesity	19.0%	19.9%	19.3%	<.001
Weight loss	4.5%	5.7%	4.9%	<.001
Fluid and electrolyte disorders	27.4%	33.2%	28.0%	<.001
Blood loss anemia	0.3%	0.6%	0.3%	<.001
Deficiency anemia	14.4%	22.3%	17.0%	<.001
Alcohol abuse	4.5%	4.7%	4.9%	<.001
Drug abuse	3.5%	3.9%	4.7%	<.001
Psychoses	6.1%	7.4%	7.8%	<.001
Depression	16.7%	17.0%	18.7%	<.001

Note: Unweighted N's displayed. Frequencies derived using weighted analysis.

Appendix Table 4: Top 20 Diagnosis Related Groups (DRGs) for non-COPD related readmissions

Rank	Diagnosis Related Group	%
1	871: Septicemia or severe sepsis without mechanical ventilation for > 96 hours with major complication or comorbidity	7.8%
2	291: Heart failure and shock with major complication or comorbidity	5.6%
3	193: Simple pneumonia and pleurisy with major complication or comorbidity	5.4%
4	194: Simple pneumonia and pleurisy with complication or comorbidity	4.2%
5	292: Heart failure and shock with complication or comorbidity	3.5%
6	177: Respiratory infections and inflammations with major complication or comorbidity	2.5%
7	392: Esophagitis, gastroenteritis, and miscellaneous digestive disorders without major comorbidity or complication	2.4%
8	178: Respiratory infections and inflammations with complication or comorbidity	1.7%
9	309: Cardiac arrhythmia and conduction disorders with complication or comorbidity	1.6%
10	885: Psychoses	1.5%
11	683: Renal failure with comorbidity or complication	1.5%
12	313: Chest pain	1.5%
13	378: Gastrointestinal hemorrhage with comorbidity or complication	1.4%
14	641: Miscellaneous disorders of nutrition, metabolism, or fluids/electrolytes without major comorbidity or complication	1.4%
15	603: Cellulitis without major comorbidity or complication	1.4%
16	189: Pulmonary edema and respiratory failure	1.2%
17	308: Cardiac arrhythmia and conduction disorders with major complication or comorbidity	1.2%
18	682: Renal failure with major comorbidity or complication	1.2%
19	312: Syncope and collapse	1.2%
20	All Others	51.5%

Appendix Table 5: Top 10 DRGs, COPD readmissions by HRRP Criteria

DRG Rank	2010 Dx	%	2011 Dx	%	2012 Dx	%	2013 Dx	%	2014 Dx	%	2015 Dx	%	2016 Dx	%
1	191: CHRONIC OBSTRUCTIVE PULMONARY DISEASE W CC	25.70%	191: CHRONIC OBSTRUCTIVE PULMONARY DISEASE W CC	26.80%	191: CHRONIC OBSTRUCTIVE PULMONARY DISEASE W CC	26.00%	191: CHRONIC OBSTRUCTIVE PULMONARY DISEASE W CC	25.60%	190: CHRONIC OBSTRUCTIVE PULMONARY DISEASE W MCC	26.40%	190: CHRONIC OBSTRUCTIVE PULMONARY DISEASE W MCC	27.40%	190: CHRONIC OBSTRUCTIVE PULMONARY DISEASE W MCC	30.40%
2	192: CHRONIC OBSTRUCTIVE PULMONARY DISEASE W/O CC/MCC	24.70%	190: CHRONIC OBSTRUCTIVE PULMONARY DISEASE W MCC	24.30%	190: CHRONIC OBSTRUCTIVE PULMONARY DISEASE W MCC	24.50%	190: CHRONIC OBSTRUCTIVE PULMONARY DISEASE W MCC	25.40%	191: CHRONIC OBSTRUCTIVE PULMONARY DISEASE W CC	24.50%	189: PULMONARY EDEMA & RESPIRATORY FAILURE	25.60%	189: PULMONARY EDEMA & RESPIRATORY FAILURE	28.30%
3	190: CHRONIC OBSTRUCTIVE PULMONARY DISEASE W MCC	23.60%	192: CHRONIC OBSTRUCTIVE PULMONARY DISEASE W/O CC/MCC	22.40%	192: CHRONIC OBSTRUCTIVE PULMONARY DISEASE W/O CC/MCC	20.70%	189: PULMONARY EDEMA & RESPIRATORY FAILURE	20.70%	189: PULMONARY EDEMA & RESPIRATORY FAILURE	23.00%	191: CHRONIC OBSTRUCTIVE PULMONARY DISEASE W CC	24.00%	191: CHRONIC OBSTRUCTIVE PULMONARY DISEASE W CC	21.20%
4	189: PULMONARY EDEMA & RESPIRATORY FAILURE	16.10%	189: PULMONARY EDEMA & RESPIRATORY FAILURE	17.20%	189: PULMONARY EDEMA & RESPIRATORY FAILURE	18.80%	192: CHRONIC OBSTRUCTIVE PULMONARY DISEASE W/O CC/MCC	18.50%	192: CHRONIC OBSTRUCTIVE PULMONARY DISEASE W/O CC/MCC	16.40%	192: CHRONIC OBSTRUCTIVE PULMONARY DISEASE W/O CC/MCC	13.30%	192: CHRONIC OBSTRUCTIVE PULMONARY DISEASE W/O CC/MCC	10.20%
5	208: RESPIRATORY SYSTEM DIAGNOSIS W VENTILATOR SUPPORT <96 HOURS	5.40%	208: RESPIRATORY SYSTEM DIAGNOSIS W VENTILATOR SUPPORT <96 HOURS	5.30%	208: RESPIRATORY SYSTEM DIAGNOSIS W VENTILATOR SUPPORT <96 HOURS	6.30%	208: RESPIRATORY SYSTEM DIAGNOSIS W VENTILATOR SUPPORT <96 HOURS	6.30%	208: RESPIRATORY SYSTEM DIAGNOSIS W VENTILATOR SUPPORT <96 HOURS	6.20%	208: RESPIRATORY SYSTEM DIAGNOSIS W VENTILATOR SUPPORT <96 HOURS	6.00%	208: RESPIRATORY SYSTEM DIAGNOSIS W VENTILATOR SUPPORT <96 HOURS	6.30%
6	207: RESPIRATORY SYSTEM DIAGNOSIS W VENTILATOR SUPPORT >96 HOURS	2.30%	207: RESPIRATORY SYSTEM DIAGNOSIS W VENTILATOR SUPPORT >96 HOURS	2.10%	207: RESPIRATORY SYSTEM DIAGNOSIS W VENTILATOR SUPPORT >96 HOURS	1.80%	207: RESPIRATORY SYSTEM DIAGNOSIS W VENTILATOR SUPPORT >96 HOURS	1.70%	207: RESPIRATORY SYSTEM DIAGNOSIS W VENTILATOR SUPPORT >96 HOURS	1.70%	207: RESPIRATORY SYSTEM DIAGNOSIS W VENTILATOR SUPPORT >96 HOURS	1.70%	207: RESPIRATORY SYSTEM DIAGNOSIS W VENTILATOR SUPPORT >96 HOURS	1.60%
7	4: TRACH W MV >96 HRS OR PDX EXC FACE, MOUTH & NECK W/O MAJ O.R.	0.60%	4: TRACH W MV >96 HRS OR PDX EXC FACE, MOUTH & NECK W/O MAJ O.R.	0.50%	4: TRACH W MV >96 HRS OR PDX EXC FACE, MOUTH & NECK W/O MAJ O.R.	0.50%	4: TRACH W MV >96 HRS OR PDX EXC FACE, MOUTH & NECK W/O MAJ O.R.	0.60%	4: TRACH W MV >96 HRS OR PDX EXC FACE, MOUTH & NECK W/O MAJ O.R.	0.40%	4: TRACH W MV >96 HRS OR PDX EXC FACE, MOUTH & NECK W/O MAJ O.R.	0.50%	166: OTHER RESP SYSTEM O.R. PROCEDURES W MCC	0.50%
8	166: OTHER RESP SYSTEM O.R. PROCEDURES W MCC	0.50%	981: EXTENSIVE O.R. PROCEDURE UNRELATED TO PRINCIPAL DIAGNOSIS W MCC	0.30%	981: EXTENSIVE O.R. PROCEDURE UNRELATED TO PRINCIPAL DIAGNOSIS W MCC	0.30%	981: EXTENSIVE O.R. PROCEDURE UNRELATED TO PRINCIPAL DIAGNOSIS W MCC	0.40%	166: OTHER RESP SYSTEM O.R. PROCEDURES W MCC	0.40%	166: OTHER RESP SYSTEM O.R. PROCEDURES W MCC	0.40%	4: TRACH W MV >96 HRS OR PDX EXC FACE, MOUTH & NECK W/O MAJ O.R.	0.50%
9	981: EXTENSIVE O.R. PROCEDURE UNRELATED TO PRINCIPAL DIAGNOSIS W MCC	0.30%	166: OTHER RESP SYSTEM O.R. PROCEDURES W MCC	0.30%	166: OTHER RESP SYSTEM O.R. PROCEDURES W MCC	0.30%	166: OTHER RESP SYSTEM O.R. PROCEDURES W MCC	0.40%	981: EXTENSIVE O.R. PROCEDURE UNRELATED TO PRINCIPAL DIAGNOSIS W MCC	0.20%	981: EXTENSIVE O.R. PROCEDURE UNRELATED TO PRINCIPAL DIAGNOSIS W MCC	0.30%	981: EXTENSIVE O.R. PROCEDURE UNRELATED TO PRINCIPAL DIAGNOSIS W MCC	0.30%
10	999: UNGROUPABLE	0.20%	999: UNGROUPABLE	0.20%	999: UNGROUPABLE	0.10%	999: UNGROUPABLE	0.20%	999: UNGROUPABLE	0.20%	167: OTHER RESP SYSTEM O.R. PROCEDURES W CC	0.10%	163: MAJOR CHEST PROCEDURES W MCC	0.20%

Appendix Table 6: Top 10 DRGs, non-COPD readmissions by HRRP Criteria

DRG Rank	2010 Dx	%	2011 Dx	%	2012 Dx	%	2013 Dx	%	2014 Dx	%	2015 Dx	%	2016 Dx	%
1	194: SIMPLE PNEUMONIA & PLEURISY W CC	5.1%	871: SEPTICEMIA OR SEVERE SEPSIS W/O MV >96 HOURS W MCC	5.6%	871: SEPTICEMIA OR SEVERE SEPSIS W/O MV >96 HOURS W MCC	6.3%	871: SEPTICEMIA OR SEVERE SEPSIS W/O MV >96 HOURS W MCC	7.8%	871: SEPTICEMIA OR SEVERE SEPSIS W/O MV >96 HOURS W MCC	8.9%	871: SEPTICEMIA OR SEVERE SEPSIS W/O MV >96 HOURS W MCC	10.4%	871: SEPTICEMIA OR SEVERE SEPSIS W/O MV >96 HOURS W MCC	11.3%
2	871: SEPTICEMIA OR SEVERE SEPSIS W/O MV >96 HOURS W MCC	5.0%	193: SIMPLE PNEUMONIA & PLEURISY W MCC	5.2%	193: SIMPLE PNEUMONIA & PLEURISY W MCC	5.5%	193: SIMPLE PNEUMONIA & PLEURISY W MCC	5.7%	291: HEART FAILURE & SHOCK W MCC	6.1%	291: HEART FAILURE & SHOCK W MCC	6.6%	291: HEART FAILURE & SHOCK W MCC	7.9%
3	193: SIMPLE PNEUMONIA & PLEURISY W MCC	4.9%	194: SIMPLE PNEUMONIA & PLEURISY W CC	5.1%	291: HEART FAILURE & SHOCK W MCC	4.8%	291: HEART FAILURE & SHOCK W MCC	5.5%	193: SIMPLE PNEUMONIA & PLEURISY W MCC	5.5%	193: SIMPLE PNEUMONIA & PLEURISY W MCC	5.7%	193: SIMPLE PNEUMONIA & PLEURISY W MCC	5.4%
4	291: HEART FAILURE & SHOCK W MCC	4.4%	291: HEART FAILURE & SHOCK W MCC	4.4%	194: SIMPLE PNEUMONIA & PLEURISY W CC	4.4%	194: SIMPLE PNEUMONIA & PLEURISY W CC	4.4%	194: SIMPLE PNEUMONIA & PLEURISY W CC	4.0%	292: HEART FAILURE & SHOCK W CC	3.5%	292: HEART FAILURE & SHOCK W CC	3.2%
5	292: HEART FAILURE & SHOCK W CC	3.4%	292: HEART FAILURE & SHOCK W CC	3.7%	292: HEART FAILURE & SHOCK W CC	3.8%	292: HEART FAILURE & SHOCK W CC	3.5%	292: HEART FAILURE & SHOCK W CC	3.6%	194: SIMPLE PNEUMONIA & PLEURISY W CC	3.3%	194: SIMPLE PNEUMONIA & PLEURISY W CC	3.0%
6	392: ESOPHAGITIS, GASTROENT & MISC DIGEST DISORDERS W/O MCC	2.7%	392: ESOPHAGITIS, GASTROENT & MISC DIGEST DISORDERS W/O MCC	2.9%	392: ESOPHAGITIS, GASTROENT & MISC DIGEST DISORDERS W/O MCC	2.6%	177: RESPIRATORY INFECTIONS & INFLAMMATIONS W MCC	2.5%	177: RESPIRATORY INFECTIONS & INFLAMMATIONS W MCC	2.5%	177: RESPIRATORY INFECTIONS & INFLAMMATIONS W MCC	2.6%	177: RESPIRATORY INFECTIONS & INFLAMMATIONS W MCC	2.6%
7	177: RESPIRATORY INFECTIONS & INFLAMMATIONS W MCC	2.4%	177: RESPIRATORY INFECTIONS & INFLAMMATIONS W MCC	2.3%	177: RESPIRATORY INFECTIONS & INFLAMMATIONS W MCC	2.2%	392: ESOPHAGITIS, GASTROENT & MISC DIGEST DISORDERS W/O MCC	2.3%	392: ESOPHAGITIS, GASTROENT & MISC DIGEST DISORDERS W/O MCC	2.3%	392: ESOPHAGITIS, GASTROENT & MISC DIGEST DISORDERS W/O MCC	1.9%	392: ESOPHAGITIS, GASTROENT & MISC DIGEST DISORDERS W/O MCC	1.8%
8	178: RESPIRATORY INFECTIONS & INFLAMMATIONS W CC	2.2%	178: RESPIRATORY INFECTIONS & INFLAMMATIONS W CC	2.0%	178: RESPIRATORY INFECTIONS & INFLAMMATIONS W CC	1.8%	885: PSYCHOSES	1.7%	309: CARDIAC ARRHYTHMIA & CONDUCTION DISORDERS W CC	1.7%	309: CARDIAC ARRHYTHMIA & CONDUCTION DISORDERS W CC	1.6%	683: RENAL FAILURE W CC	1.5%
9	313: CHEST PAIN	2.0%	313: CHEST PAIN	2.0%	378: G.I. HEMORRHAGE W CC	1.7%	683: RENAL FAILURE W CC	1.7%	683: RENAL FAILURE W CC	1.6%	683: RENAL FAILURE W CC	1.6%	309: CARDIAC ARRHYTHMIA & CONDUCTION DISORDERS W CC	1.5%
10	885: PSYCHOSES	1.8%	885: PSYCHOSES	1.7%	683: RENAL FAILURE W CC	1.6%	309: CARDIAC ARRHYTHMIA & CONDUCTION DISORDERS W CC	1.7%	178: RESPIRATORY INFECTIONS & INFLAMMATIONS W CC	1.6%	378: G.I. HEMORRHAGE W CC	1.4%	682: RENAL FAILURE W MCC	1.4%

Appendix Table 7: Top 10 DRGs, respiratory readmissions by DRG criteria

DRG Rank	2010 Dx	%	2011 Dx	%	2012 Dx	%	2013 Dx	%	2014 Dx	%	2015 Dx	%	2016 Dx	%
1	191: CHRONIC OBSTRUCTIVE PULMONARY DISEASE W CC	19.9%	191: CHRONIC OBSTRUCTIVE PULMONARY DISEASE W CC	20.8%	191: CHRONIC OBSTRUCTIVE PULMONARY DISEASE W CC	20.5%	191: CHRONIC OBSTRUCTIVE PULMONARY DISEASE W CC	20.0%	190: CHRONIC OBSTRUCTIVE PULMONARY DISEASE W MCC	20.5%	190: CHRONIC OBSTRUCTIVE PULMONARY DISEASE W MCC	21.5%	190: CHRONIC OBSTRUCTIVE PULMONARY DISEASE W MCC	24.0%
2	192: CHRONIC OBSTRUCTIVE PULMONARY DISEASE W/O CC/MCC	19.1%	190: CHRONIC OBSTRUCTIVE PULMONARY DISEASE W MCC	18.8%	190: CHRONIC OBSTRUCTIVE PULMONARY DISEASE W MCC	19.1%	190: CHRONIC OBSTRUCTIVE PULMONARY DISEASE W MCC	19.7%	189: PULMONARY EDEMA & RESPIRATORY FAILURE	19.3%	189: PULMONARY EDEMA & RESPIRATORY FAILURE	21.4%	189: PULMONARY EDEMA & RESPIRATORY FAILURE	23.4%
3	190: CHRONIC OBSTRUCTIVE PULMONARY DISEASE W MCC	18.3%	192: CHRONIC OBSTRUCTIVE PULMONARY DISEASE W/O CC/MCC	17.3%	192: CHRONIC OBSTRUCTIVE PULMONARY DISEASE W/O CC/MCC	16.2%	189: PULMONARY EDEMA & RESPIRATORY FAILURE	17.1%	191: CHRONIC OBSTRUCTIVE PULMONARY DISEASE W CC	19.2%	191: CHRONIC OBSTRUCTIVE PULMONARY DISEASE W CC	18.9%	191: CHRONIC OBSTRUCTIVE PULMONARY DISEASE W CC	16.8%
4	189: PULMONARY EDEMA & RESPIRATORY FAILURE	13.3%	189: PULMONARY EDEMA & RESPIRATORY FAILURE	14.2%	189: PULMONARY EDEMA & RESPIRATORY FAILURE	15.5%	192: CHRONIC OBSTRUCTIVE PULMONARY DISEASE W/O CC/MCC	14.4%	192: CHRONIC OBSTRUCTIVE PULMONARY DISEASE W/O CC/MCC	12.8%	192: CHRONIC OBSTRUCTIVE PULMONARY DISEASE W/O CC/MCC	10.5%	192: CHRONIC OBSTRUCTIVE PULMONARY DISEASE W/O CC/MCC	8.0%
5	208: RESPIRATORY SYSTEM DIAGNOSIS W VENTILATOR SUPPORT <96 HOURS	5.0%	208: RESPIRATORY SYSTEM DIAGNOSIS W VENTILATOR SUPPORT <96 HOURS	5.0%	208: RESPIRATORY SYSTEM DIAGNOSIS W VENTILATOR SUPPORT <96 HOURS	5.8%	208: RESPIRATORY SYSTEM DIAGNOSIS W VENTILATOR SUPPORT <96 HOURS	5.8%	208: RESPIRATORY SYSTEM DIAGNOSIS W VENTILATOR SUPPORT <96 HOURS	5.7%	193: SIMPLE PNEUMONIA & PLEURISY W MCC	5.7%	208: RESPIRATORY SYSTEM DIAGNOSIS W VENTILATOR SUPPORT <96 HOURS	5.8%
6	194: SIMPLE PNEUMONIA & PLEURISY W CC	4.9%	193: SIMPLE PNEUMONIA & PLEURISY W MCC	4.9%	193: SIMPLE PNEUMONIA & PLEURISY W MCC	5.2%	193: SIMPLE PNEUMONIA & PLEURISY W MCC	5.5%	193: SIMPLE PNEUMONIA & PLEURISY W MCC	5.3%	208: RESPIRATORY SYSTEM DIAGNOSIS W VENTILATOR SUPPORT <96 HOURS	5.7%	193: SIMPLE PNEUMONIA & PLEURISY W MCC	5.4%
7	193: SIMPLE PNEUMONIA & PLEURISY W MCC	4.6%	194: SIMPLE PNEUMONIA & PLEURISY W CC	4.8%	194: SIMPLE PNEUMONIA & PLEURISY W CC	4.2%	194: SIMPLE PNEUMONIA & PLEURISY W CC	4.2%	194: SIMPLE PNEUMONIA & PLEURISY W CC	3.9%	194: SIMPLE PNEUMONIA & PLEURISY W CC	3.3%	194: SIMPLE PNEUMONIA & PLEURISY W CC	3.1%
8	177: RESPIRATORY INFECTIONS & INFLAMMATIONS W MCC	2.3%	177: RESPIRATORY INFECTIONS & INFLAMMATIONS W MCC	2.2%	177: RESPIRATORY INFECTIONS & INFLAMMATIONS W MCC	2.0%	177: RESPIRATORY INFECTIONS & INFLAMMATIONS W MCC	2.4%	177: RESPIRATORY INFECTIONS & INFLAMMATIONS W MCC	2.4%	177: RESPIRATORY INFECTIONS & INFLAMMATIONS W MCC	2.6%	177: RESPIRATORY INFECTIONS & INFLAMMATIONS W MCC	2.6%
9	207: RESPIRATORY SYSTEM DIAGNOSIS W VENTILATOR SUPPORT >96 HOURS	2.3%	207: RESPIRATORY SYSTEM DIAGNOSIS W VENTILATOR SUPPORT >96 HOURS	2.1%	207: RESPIRATORY SYSTEM DIAGNOSIS W VENTILATOR SUPPORT >96 HOURS	1.9%	207: RESPIRATORY SYSTEM DIAGNOSIS W VENTILATOR SUPPORT >96 HOURS	1.8%	207: RESPIRATORY SYSTEM DIAGNOSIS W VENTILATOR SUPPORT >96 HOURS	1.8%	207: RESPIRATORY SYSTEM DIAGNOSIS W VENTILATOR SUPPORT >96 HOURS	1.7%	207: RESPIRATORY SYSTEM DIAGNOSIS W VENTILATOR SUPPORT >96 HOURS	1.5%
10	178: RESPIRATORY INFECTIONS & INFLAMMATIONS W CC	2.1%	178: RESPIRATORY INFECTIONS & INFLAMMATIONS W CC	1.9%	178: RESPIRATORY INFECTIONS & INFLAMMATIONS W CC	1.7%	178: RESPIRATORY INFECTIONS & INFLAMMATIONS W CC	1.5%	178: RESPIRATORY INFECTIONS & INFLAMMATIONS W CC	1.5%	178: RESPIRATORY INFECTIONS & INFLAMMATIONS W CC	1.3%	178: RESPIRATORY INFECTIONS & INFLAMMATIONS W CC	1.1%

Appendix Table 8: Top 10 DRGs, non-respiratory readmissions by DRG criteria

DRG Rank	2010 Dx	%	2011 Dx	%	2012 Dx	%	2013 Dx	%	2014 Dx	%	2015 Dx	%	2016 Dx	%
1	871: SEPTICEMIA OR SEVERE SEPSIS W/O MV >96 HOURS W MCC	6.7%	871: SEPTICEMIA OR SEVERE SEPSIS W/O MV >96 HOURS W MCC	7.5%	871: SEPTICEMIA OR SEVERE SEPSIS W/O MV >96 HOURS W MCC	8.3%	871: SEPTICEMIA OR SEVERE SEPSIS W/O MV >96 HOURS W MCC	10.2%	871: SEPTICEMIA OR SEVERE SEPSIS W/O MV >96 HOURS W MCC	11.6%	871: SEPTICEMIA OR SEVERE SEPSIS W/O MV >96 HOURS W MCC	13.3%	871: SEPTICEMIA OR SEVERE SEPSIS W/O MV >96 HOURS W MCC	14.3%
2	291: HEART FAILURE & SHOCK W MCC	5.9%	291: HEART FAILURE & SHOCK W MCC	5.8%	291: HEART FAILURE & SHOCK W MCC	6.4%	291: HEART FAILURE & SHOCK W MCC	7.2%	291: HEART FAILURE & SHOCK W MCC	8.0%	291: HEART FAILURE & SHOCK W MCC	8.5%	291: HEART FAILURE & SHOCK W MCC	10.0%
3	292: HEART FAILURE & SHOCK W CC	4.5%	292: HEART FAILURE & SHOCK W CC	4.9%	292: HEART FAILURE & SHOCK W CC	5.0%	292: HEART FAILURE & SHOCK W CC	4.6%	292: HEART FAILURE & SHOCK W CC	4.8%	292: HEART FAILURE & SHOCK W CC	4.5%	292: HEART FAILURE & SHOCK W CC	4.1%
4	392: ESOPHAGITIS, GASTROENT & MISC DIGEST DISORDERS W/O MCC	3.6%	392: ESOPHAGITIS, GASTROENT & MISC DIGEST DISORDERS W/O MCC	3.8%	392: ESOPHAGITIS, GASTROENT & MISC DIGEST DISORDERS W/O MCC	3.4%	392: ESOPHAGITIS, GASTROENT & MISC DIGEST DISORDERS W/O MCC	3.1%	392: ESOPHAGITIS, GASTROENT & MISC DIGEST DISORDERS W/O MCC	3.0%	392: ESOPHAGITIS, GASTROENT & MISC DIGEST DISORDERS W/O MCC	2.5%	392: ESOPHAGITIS, GASTROENT & MISC DIGEST DISORDERS W/O MCC	2.3%
5	313: CHEST PAIN	2.7%	313: CHEST PAIN	2.6%	378: G.I. HEMORRHAGE W CC	2.2%	885: PSYCHOSES	2.3%	309: CARDIAC ARRHYTHMIA & CONDUCTION DISORDERS W CC	2.2%	309: CARDIAC ARRHYTHMIA & CONDUCTION DISORDERS W CC	2.1%	683: RENAL FAILURE W CC	1.9%
6	885: PSYCHOSES	2.4%	885: PSYCHOSES	2.3%	683: RENAL FAILURE W CC	2.2%	683: RENAL FAILURE W CC	2.3%	683: RENAL FAILURE W CC	2.1%	683: RENAL FAILURE W CC	2.0%	309: CARDIAC ARRHYTHMIA & CONDUCTION DISORDERS W CC	1.9%
7	641: MISC DISORDERS OF NUTRITION, METABOLISM, FLUIDS/ELECTROLYTES W/O MCC	2.2%	309: CARDIAC ARRHYTHMIA & CONDUCTION DISORDERS W CC	2.2%	313: CHEST PAIN	2.1%	309: CARDIAC ARRHYTHMIA & CONDUCTION DISORDERS W CC	2.3%	378: G.I. HEMORRHAGE W CC	2.0%	378: G.I. HEMORRHAGE W CC	1.8%	682: RENAL FAILURE W MCC	1.8%
8	603: CELLULITIS W/O MCC	2.0%	641: MISC DISORDERS OF NUTRITION, METABOLISM, FLUIDS/ ELECTROLYTES W/O MCC	2.2%	641: MISC DISORDERS OF NUTRITION, METABOLISM, FLUIDS/ ELECTROLYTES W/O MCC	2.0%	378: G.I. HEMORRHAGE W CC	2.1%	885: PSYCHOSES	1.9%	872: SEPTICEMIA OR SEVERE SEPSIS W/O MV >96 HOURS W/O MCC	1.8%	872: SEPTICEMIA OR SEVERE SEPSIS W/O MV >96 HOURS W/O MCC	1.7%
9	309: CARDIAC ARRHYTHMIA & CONDUCTION DISORDERS W CC	1.9%	683: RENAL FAILURE W CC	1.9%	309: CARDIAC ARRHYTHMIA & CONDUCTION DISORDERS W CC	2.0%	313: CHEST PAIN	1.9%	308: CARDIAC ARRHYTHMIA & CONDUCTION DISORDERS W MCC	1.8%	682: RENAL FAILURE W MCC	1.7%	308: CARDIAC ARRHYTHMIA & CONDUCTION DISORDERS W MCC	1.6%
10	312: SYNCOPE & COLLAPSE	1.9%	603: CELLULITIS W/O MCC	1.9%	885: PSYCHOSES	2.0%	603: CELLULITIS W/O MCC	1.8%	682: RENAL FAILURE W MCC	1.7%	641: MISC DISORDERS OF NUTRITION, METABOLISM, FLUIDS/ ELECTROLYTES W/O MCC	1.7%	885: PSYCHOSES	1.6%

Appendix Table 9: Naïve, partial, and fully adjusted multilevel multinomial logistic regression models of readmission with hospital level random intercepts, by HRRP criteria for COPD versus non-COPD readmissions

Model Info	Naïve Model		Patient Covariates		Fully Adjusted	
N	1,662,983		1,659,576		1,658,372	
LL	-2,128,251.5		-2,114,269.5		-2,105,502.3	
df	5		43		81	
AIC	4,256,513.0		4,228,625.0		4,211,166.5	
BIC	4,256,574.5		4,229,155.0		4,212,164.5	
Predictors	**Non-COPD** ref=Not Readmitted	**COPD** ref=Not Readmitted	**Non-COPD** ref=Not Readmitted	**COPD** ref=Not Readmitted	**Non-COPD** ref=Not Readmitted	**COPD** ref=Not Readmitted
Elixhauser (per ½ SD)	*1.22 (1.22, 1.23)	*1.06 (1.06, 1.06)	*1.21 (1.21, 1.21)	*1.06 (1.05, 1.06)	*1.19 (1.19, 1.19)	*1.04 (1.04, 1.05)
Year (ref=2010)						
2011			0.98 (0.96, 1.01)	1.01 (0.98, 1.04)	0.98 (0.96, 1.01)	1.00 (0.97, 1.03)
2012			*0.94 (0.91, 0.97)	*0.97 (0.94, 1.00)	*0.94 (0.92, 0.97)	*0.96 (0.93, 0.99)
2013			*0.90 (0.87, 0.92)	*0.93 (0.90, 0.96)	*0.90 (0.88, 0.93)	*0.92 (0.89, 0.95)
2014			*0.88 (0.85, 0.90)	*0.91 (0.88, 0.94)	*0.86 (0.84, 0.88)	*0.92 (0.89, 0.95)
2015			*0.85 (0.83, 0.87)	*0.87 (0.84, 0.89)	*0.86 (0.84, 0.89)	*0.85 (0.82, 0.87)
2016			*0.84 (0.82, 0.87)	*0.88 (0.85, 0.90)	*0.85 (0.82, 0.87)	*0.86 (0.83, 0.88)
Quarter (ref=1st)						
2nd Quarter			*0.95 (0.94, 0.97)	*0.97 (0.96, 0.99)	*0.96 (0.94, 0.98)	*0.97 (0.96, 0.99)
3rd Quarter			*0.97 (0.96, 0.99)	*1.03 (1.01, 1.05)	*0.98 (0.96, 1.00)	*1.03 (1.01, 1.05)
4th Quarter			*0.95 (0.93, 0.97)	*1.02 (1.00, 1.04)	*0.96 (0.94, 0.98)	*1.02 (1.00, 1.04)
Sex (ref=male)						
Female			*0.94 (0.93, 0.95)	*0.92 (0.91, 0.94)	*0.92 (0.91, 0.93)	*0.91 (0.90, 0.93)
Age (per 10 years)			*1.10 (1.09, 1.11)	*0.90 (0.90, 0.91)	*1.06 (1.05, 1.07)	*0.89 (0.89, 0.90)
Income Quartile (ref=1st)						
2nd Quartile			1.00 (0.98, 1.02)	*0.97 (0.95, 0.99)	0.99 (0.98, 1.01)	*0.97 (0.95, 0.98)
3rd Quartile			0.99 (0.98, 1.01)	*0.97 (0.95, 0.99)	0.99 (0.97, 1.00)	*0.95 (0.93, 0.97)
4th Quartile			1.00 (0.97, 1.02)	*0.94 (0.91, 0.96)	0.98 (0.96, 1.00)	*0.91 (0.89, 0.94)
Missing			0.95 (0.90, 1.00)	0.99 (0.94, 1.05)	*0.95 (0.90, 1.00)	0.99 (0.94, 1.05)
Payer (ref=Medicare)						
Medicaid			*1.02 (1.00, 1.05)	*1.10 (1.07, 1.12)	*1.03 (1.01, 1.06)	*1.10 (1.07, 1.12)
Private			*0.74 (0.72, 0.76)	*0.64 (0.63, 0.66)	*0.76 (0.74, 0.78)	*0.65 (0.63, 0.67)
Self-Pay			*0.60 (0.57, 0.63)	*0.60 (0.57, 0.63)	*0.62 (0.59, 0.65)	*0.62 (0.59, 0.65)
Other/No Charge			*0.76 (0.73, 0.79)	*0.80 (0.76, 0.83)	*0.77 (0.74, 0.80)	*0.81 (0.78, 0.85)
Disposition (ref=Routine to home)						
Post-acute care					*1.35	1.00

	Column 1	Column 2
	(1.33, 1.38)	(0.98, 1.03)
Other	*1.19	0.92
	(1.11, 1.28)	(0.83, 1.01)
Home Health	*1.31	*1.30
	(1.29, 1.34)	(1.27, 1.32)
LOS *(per day)*	*1.02	*1.01
	(1.01, 1.02)	(1.00, 1.01)
Care intensity *(ref=No)*		
Non-invasive ventilation	*0.89	*1.37
	(0.87, 0.91)	(1.34, 1.40)
Mechanical ventilation	*0.79	*0.87
	(0.76, 0.81)	(0.84, 0.91)
Tracheostomy	1.07	1.01
	(1.00, 1.14)	(0.92, 1.10)
Cardiac arrest	*0.87	*0.68
	(0.77, 0.98)	(0.58, 0.81)
CPR	1.15	0.98
	(0.98, 1.34)	(0.80, 1.21)
Hospital ownership *(ref=government)*		
Private, non-profit	*0.97	0.99
	(0.95, 0.99)	(0.97, 1.01)
Private, for-profit	*1.05	1.01
	(1.03, 1.08)	(0.98, 1.04)
Hospital teaching status *(ref=Non-teaching)*		
Teaching Hospital	0.98	1.02
	(0.96, 1.00)	(1.00, 1.04)
Hospital location *(ref=Large metro area)*		
Small metro area	*0.94	*0.93
	(0.92, 0.95)	(0.91, 0.95)
Micropolitan area	*0.91	*0.89
	(0.88, 0.93)	(0.86, 0.92)
Rural	*0.88	*0.89
	(0.85, 0.92)	(0.86, 0.93)
Hospital Bed Size *(ref=Small)*		
Medium	1.01	1.01
	(0.98, 1.03)	(0.98, 1.03)
Large	1.01	1.00
	(0.99, 1.04)	(0.98, 1.03)
Annual Discharge (per 10k)	*1.02	1.00
	(1.01, 1.03)	(0.99, 1.02)
Proportion Medicaid per 10%	*0.99	*1.01
	(0.98, 1.00)	(1.00, 1.02)

Appendix Table 10: Cox Regression models of COPD Readmission (versus reference of readmission for non-COPD diagnosis) by HRRP criteria with hospital level clustering

Model Info	Model 1		Model 2		Model 3	
N	287,884		287,362		287,186	
LL	-1,486,500.3		-3,555,481.8		-3,551,449.8	
df	1		20		39	
AIC	2,973,002.5		7,111,003.5		7,102,977.5	
BIC	2,973,013.3		7,111,214.5		7,103,390.0	
Predictors	**HR (95% CI)**	**P**	**HR (95% CI)**	**P**	**HR (95% CI)**	**P**
Elixhauser Index *(per 1/2 SD)*	0.93 (0.93, 0.93)	<.001	0.93 (0.93, 0.93)	<.001	0.93 (0.93, 0.93)	<.001
Year *(ref=2010)*						
2011			1.01 (0.99, 1.04)	0.380	1.01 (0.98, 1.04)	0.487
2012			1.01 (0.98, 1.03)	0.617	1.00 (0.98, 1.03)	0.907
2013			1.00 (0.98, 1.03)	0.693	1.00 (0.97, 1.02)	0.763
2014			1.00 (0.97, 1.02)	0.901	1.02 (0.99, 1.04)	0.207
2015			0.99 (0.97, 1.02)	0.449	0.97 (0.95, 1.00)	0.045
2016			1.02 (1.00, 1.04)	0.109	1.01 (0.98, 1.03)	0.551
Quarter *(ref=1ˢᵗ)*						
2ⁿᵈ Quarter			0.99 (0.97, 1.00)	0.086	0.98 (0.97, 1.00)	0.033
3ʳᵈ Quarter			0.98 (0.96, 0.99)	0.009	0.97 (0.96, 0.99)	0.002
4ᵗʰ Quarter			0.99 (0.97, 1.01)	0.405	0.99 (0.97, 1.01)	0.215
Sex *(ref=male)*						
Female			0.98 (0.96, 0.99)	<.001	0.98 (0.97, 1.00)	0.011
Age *(per 10 year)*			0.91 (0.90, 0.91)	<.001	0.92 (0.91, 0.93)	<.001
Income Quartile *(ref=1ˢᵗ)*						
2ⁿᵈ Quartile			1.00 (0.98, 1.01)	0.662	1.00 (0.98, 1.02)	0.951
3ʳᵈ Quartile			0.99 (0.98, 1.01)	0.484	1.00 (0.98, 1.02)	0.831
4ᵗʰ Quartile			0.99 (0.97, 1.01)	0.227	0.99 (0.97, 1.01)	0.502
Missing			1.02 (0.97, 1.07)	0.398	1.03 (0.98, 1.08)	0.299
Payer *(ref=Medicare)*						
Medicaid			1.02 (1.00, 1.04)	0.083	1.01 (0.99, 1.03)	0.300
Private			0.95 (0.92, 0.97)	<.001	0.94 (0.92, 0.96)	<.001
Self-Pay			0.97 (0.93, 1.01)	0.160	0.97 (0.93, 1.01)	0.173
Other/No Charge			1.03 (0.99, 1.07)	0.140	1.03 (0.99, 1.07)	0.182
Disposition *(ref=Routine to home)*						
Post-acute care					0.82 (0.81, 0.84)	<.001
Other					1.03 (0.93, 1.14)	0.539
Home Health					1.02 (1.00, 1.04)	0.020
Length of stay *(per day)*					1.00 (0.99, 1.00)	<.001
Care intensity *(ref=No)*						
Non-invasive ventilation					1.23 (1.21, 1.26)	<.001
Mechanical ventilation					1.12 (1.08, 1.16)	<.001
Tracheostomy					0.87 (0.81, 0.94)	<.001
Cardiac arrest					0.97 (0.82, 1.14)	0.692
CPR					0.93 (0.75, 1.14)	0.459
Hospital ownership *(ref=government)*						
Private, non-profit					1.01 (0.99, 1.03)	0.337
Private, for-profit					1.00 (0.97, 1.02)	0.721
Hospital teaching status *(ref=Non-teaching)*						
Teaching Hospital					1.00 (0.98, 1.02)	0.840
Hospital location *(ref=Large metro area)*						
Small metro area					1.00 (0.98, 1.02)	0.966
Micropolitan area					1.01 (0.98, 1.03)	0.584

Rural	1.04 (1.00, 1.07)	0.060
Hospital Bed Size *(ref=Small)*		
Medium	0.98 (0.96, 1.01)	0.156
Large	0.97 (0.95, 0.99)	0.008
Annual Discharge (per 10k)	1.00 (1.00, 1.01)	0.375
Proportion hospital Medicaid patient days per 10%	1.01 (1.01, 1.02)	<.001

Note: Hazard Ratios with 95% Confidence Intervals Presented. * denotes p <0.05

Appendix Table 11: Naïve, partial, and fully adjusted multilevel multinomial logistic regression models of readmission with hospital level random intercepts, by DRG groupings of respiratory versus non-respiratory readmissions

Model Info	Naïve Model		Patient Covariates		Fully Adjusted	
N	1,662,983		1,659,576		1,658,372	
LL	-2,124,155.3		-2,112,156.3		-2,104,503.5	
df	5		43		81	
AIC	4,248,320.5		4,224,398.5		4,209,169.0	
BIC	4,248,382.5		4,224,928.5		4,210,167.5	
Predictors	Non-Respiratory *ref=Not Readmitted*	Respiratory *ref=Not Readmitted*	Non-Respiratory *ref=Not Readmitted*	Respiratory *ref=Not Readmitted*	Non-Respiratory *ref=Not Readmitted*	Respiratory *ref=Not Readmitted*
Elixhauser	*1.24	*1.08	*1.24	*1.08	*1.21	*1.05
(per ½ SD)	(1.24, 1.24)	(1.08, 1.08)	(1.24, 1.24)	(1.08, 1.08)	(1.21, 1.21)	(1.05, 1.05)
Year *(ref=2010)*						
2011			0.98	1.00	0.99	1.00
			(0.95, 1.02)	(0.97, 1.03)	(0.96, 1.02)	(0.97, 1.02)
2012			*0.95	*0.95	*0.95	*0.95
			(0.92, 0.98)	(0.93, 0.98)	(0.92, 0.98)	(0.92, 0.98)
2013			*0.91	*0.92	*0.91	*0.91
			(0.88, 0.94)	(0.89, 0.94)	(0.89, 0.94)	(0.89, 0.94)
2014			*0.89	*0.89	*0.87	*0.90
			(0.86, 0.92)	(0.87, 0.92)	(0.84, 0.90)	(0.88, 0.92)
2015			*0.88	*0.84	*0.89	*0.83
			(0.85, 0.91)	(0.82, 0.86)	(0.86, 0.92)	(0.81, 0.86)
2016			*0.88	*0.84	*0.88	*0.83
			(0.85, 0.91)	(0.82, 0.86)	(0.86, 0.91)	(0.81, 0.85)
Quarter *(ref=1st)*						
2nd Quarter			*0.97	*0.96	*0.98	*0.96
			(0.95, 0.99)	(0.94, 0.97)	(0.96, 0.99)	(0.94, 0.97)
3rd Quarter			1.00	1.00	1.00	1.00
			(0.98, 1.02)	(0.98, 1.02)	(0.98, 1.02)	(0.98, 1.02)
4th Quarter			*0.98	0.99	0.98	0.99
			(0.96, 1.00)	(0.97, 1.01)	(0.96, 1.00)	(0.97, 1.01)
Sex *(ref=male)*						
Female			*0.98	*0.90	*0.95	*0.89
			(0.96, 0.99)	(0.89, 0.92)	(0.94, 0.97)	(0.88, 0.90)
Age *(per 10 years)*			*1.10	*0.94	*1.06	*0.93
			(1.09, 1.10)	(0.94, 0.95)	(1.05, 1.07)	(0.92, 0.93)
Income Quartile *(ref=1st)*						
2nd Quartile			0.99	*0.98	0.99	*0.98
			(0.97, 1.01)	(0.96, 1.00)	(0.97, 1.01)	(0.96, 0.99)
3rd Quartile			0.99	*0.98	*0.97	*0.97
			(0.97, 1.01)	(0.96, 1.00)	(0.95, 0.99)	(0.95, 0.99)
4th Quartile			0.98	*0.96	*0.95	*0.94
			(0.96, 1.00)	(0.94, 0.98)	(0.93, 0.98)	(0.92, 0.97)
Missing			0.95	0.98	0.95	0.98
			(0.89, 1.01)	(0.94, 1.04)	(0.89, 1.01)	(0.94, 1.03)
Payer *(ref=Medicare)*						
Medicaid			1.02	*1.09	1.02	*1.10
			(0.99, 1.05)	(1.07, 1.12)	(1.00, 1.05)	(1.08, 1.12)
Private			*0.72	*0.68	*0.74	*0.69
			(0.70, 0.74)	(0.66, 0.69)	(0.72, 0.76)	(0.67, 0.71)
Self-Pay			*0.59	*0.61	*0.60	*0.63
			(0.56, 0.62)	(0.59, 0.63)	(0.57, 0.64)	(0.61, 0.66)
Other/No Charge			*0.76	*0.79	*0.77	*0.81
			(0.73, 0.80)	(0.76, 0.82)	(0.73, 0.81)	(0.78, 0.84)

Disposition *(ref=Routine to home)*		
Post-acute care	*1.30 (1.28, 1.33)	*1.12 (1.10, 1.15)
Other	*1.17 (1.08, 1.27)	1.00 (0.92, 1.08)
Home Health	*1.31 (1.29, 1.34)	*1.30 (1.28, 1.32)
LOS *(per day)*	*1.02 (1.01, 1.02)	*1.01 (1.01, 1.01)
Care intensity *(ref=No)*		
Non-invasive ventilation	*0.89 (0.87, 0.92)	*1.25 (1.22, 1.28)
Mechanical ventilation	*0.80 (0.77, 0.83)	*0.84 (0.81, 0.86)
Tracheostomy	*0.91 (0.84, 0.98)	*1.17 (1.09, 1.26)
Cardiac arrest	0.92 (0.81, 1.04)	*0.69 (0.60, 0.80)
CPR	*1.21 (1.03, 1.43)	0.96 (0.79, 1.15)
Hospital ownership *(ref=government)*		
Private, non-profit	0.98 (0.95, 1.00)	0.98 (0.96, 1.00)
Private, for-profit	*1.09 (1.06, 1.13)	0.99 (0.97, 1.02)
Hospital teaching status *(ref=Non-teaching)*		
Teaching Hospital	0.98 (0.96, 1.00)	1.01 (1.00, 1.03)
Hospital location *(ref=Large metro area)*		
Small metro area	*0.92 (0.90, 0.93)	*0.95 (0.93, 0.96)
Micropolitan area	*0.86 (0.83, 0.89)	*0.93 (0.90, 0.95)
Rural	*0.83 (0.80, 0.87)	*0.92 (0.89, 0.96)
Hospital Bed Size *(ref=Small)*		
Medium	*1.03 (1.01, 1.06)	0.99 (0.97, 1.01)
Large	*1.04 (1.01, 1.07)	0.99 (0.97, 1.01)
Annual Discharge (per 10k)	*1.03 (1.01, 1.04)	1.00 (0.99, 1.02)
Proportion Medicaid per 10%	1.00 (0.99, 1.01)	1.00 (0.99, 1.01)

Appendix Table 12: Multilevel multinomial logistic regression models of readmission using only covariates with hospital level random intercept.

Model Info	Model 2		Model 3	
N	1,659,576		1,658,372	
LL	-2,139,461.8		-2,123,613.0	
df	41		79	
AIC	4,279,005.5		4,247,384.0	
BIC	4,279,510.5		4,248,357.0	
Predictors	**Non-COPD** *ref=Not Readmitted*	**COPD** *ref=Not Readmitted*	**Non-COPD** *ref=Not Readmitted*	**COPD** *ref=Not Readmitted*
Year *(ref=2010)*				
2011	0.990 (0.964, 1.017)	1.008 (0.978, 1.040)	0.992 (0.966, 1.018)	1.005 (0.975, 1.036)
2012	*0.962 (0.936, 0.989)	0.975 (0.946, 1.005)	*0.961 (0.936, 0.988)	*0.965 (0.936, 0.994)
2013	*0.937 (0.913, 0.962)	*0.943 (0.915, 0.972)	*0.934 (0.910, 0.959)	*0.929 (0.902, 0.957)
2014	*0.931 (0.907, 0.956)	*0.924 (0.897, 0.952)	*0.932 (0.908, 0.958)	*0.936 (0.909, 0.964)
2015	*0.915 (0.892, 0.940)	*0.881 (0.855, 0.908)	*0.916 (0.892, 0.940)	*0.858 (0.833, 0.884)
2016	*0.921 (0.897, 0.946)	*0.897 (0.871, 0.924)	*0.918 (0.895, 0.943)	*0.869 (0.845, 0.895)
Quarter *(ref=1st)*				
2nd Quarter	*0.963 (0.947, 0.979)	*0.976 (0.958, 0.994)	*0.969 (0.952, 0.985)	*0.976 (0.958, 0.994)
3rd Quarter	0.994 (0.977, 1.012)	*1.035 (1.016, 1.055)	1.000 (0.983, 1.018)	*1.034 (1.015, 1.054)
4th Quarter	*0.967 (0.949, 0.985)	*1.026 (1.006, 1.047)	*0.978 (0.960, 0.997)	*1.027 (1.007, 1.048)
Sex *(ref=male)*				
Female	*0.905 (0.894, 0.916)	*0.916 (0.903, 0.929)	*0.880 (0.869, 0.891)	*0.905 (0.893, 0.918)
Age *(per 10 years)*	*1.128 (1.121, 1.136)	*0.909 (0.902, 0.915)	*1.075 (1.067, 1.082)	*0.896 (0.890, 0.902)
Income Quartile *(ref=1st)*				
2nd Quartile	0.990 (0.973, 1.007)	*0.967 (0.949, 0.985)	0.984 (0.967, 1.001)	*0.964 (0.946, 0.983)
3rd Quartile	0.989 (0.971, 1.007)	*0.961 (0.941, 0.980)	*0.971 (0.953, 0.989)	*0.949 (0.929, 0.969)
4th Quartile	0.984 (0.964, 1.006)	*0.933 (0.910, 0.956)	*0.952 (0.930, 0.974)	*0.912 (0.889, 0.936)
Missing	*0.932 (0.885, 0.981)	0.991 (0.937, 1.047)	*0.932 (0.885, 0.981)	0.994 (0.940, 1.051)
Payer *(ref=Medicare)*				
Medicaid	1.019 (0.996, 1.043)	*1.092 (1.067, 1.117)	*1.032 (1.008, 1.056)	*1.096 (1.071, 1.122)
Private	*0.673 (0.656, 0.691)	*0.626 (0.608, 0.644)	*0.708 (0.690, 0.726)	*0.642 (0.624, 0.661)
Self-Pay	*0.516 (0.492, 0.542)	*0.575 (0.550, 0.601)	*0.560 (0.533, 0.588)	*0.603 (0.577, 0.630)
Other/No Charge	*0.716 (0.687, 0.747)	*0.784 (0.750, 0.819)	*0.739 (0.708, 0.771)	*0.804 (0.770, 0.840)

Disposition *(ref=Routine to home)*

Post-acute care	*1.577 (1.546, 1.609)	*1.040 (1.015, 1.065)
Other	*1.361 (1.267, 1.462)	0.949 (0.862, 1.045)
Home Health	*1.454 (1.430, 1.479)	*1.328 (1.305, 1.352)
Length of Stay *(per day)*	*1.026 (1.024, 1.029)	*1.010 (1.008, 1.012)
Care intensity *(ref=No)*		
Non-invasive ventilation	0.999 (0.976, 1.023)	*1.407 (1.375, 1.440)
Mechanical ventilation	1.022 (0.988, 1.057)	*0.920 (0.885, 0.956)
Tracheostomy	1.010 (0.941, 1.083)	0.997 (0.913, 1.089)
Cardiac arrest	0.908 (0.801, 1.029)	*0.691 (0.586, 0.814)
CPR	1.160 (0.990, 1.360)	0.986 (0.802, 1.212)
Hospital ownership *(ref=government)*		
Private, non-profit	1.002 (0.980, 1.025)	0.999 (0.974, 1.024)
Private, for-profit	*1.055 (1.028, 1.083)	1.007 (0.979, 1.035)
Hospital teaching status *(ref=Non-teaching)*		
Teaching Hospital	1.013 (0.995, 1.032)	*1.025 (1.004, 1.047)
Hospital location *(ref=Large metro area)*		
Small metro area	*0.929 (0.915, 0.944)	*0.930 (0.913, 0.948)
Micropolitan area	*0.876 (0.852, 0.900)	*0.883 (0.858, 0.910)
Rural	*0.828 (0.797, 0.860)	*0.881 (0.844, 0.919)
Hospital Bed Size *(ref=Small)*		
Medium	*1.025 (1.002, 1.048)	1.014 (0.989, 1.039)
Large	*1.055 (1.030, 1.080)	1.012 (0.986, 1.038)
Annual Discharge (per 10k)	1.010 (0.998, 1.022)	1.004 (0.993, 1.016)
Proportion hospital Medicaid patient days per 10%	*0.991 (0.983, 0.998)	*1.010 (1.001, 1.018)

Note: Odds Ratios with 95% Confidence Intervals presented. * denotes p <0.05

A — Model 1
B — Model 2
C — Model 3
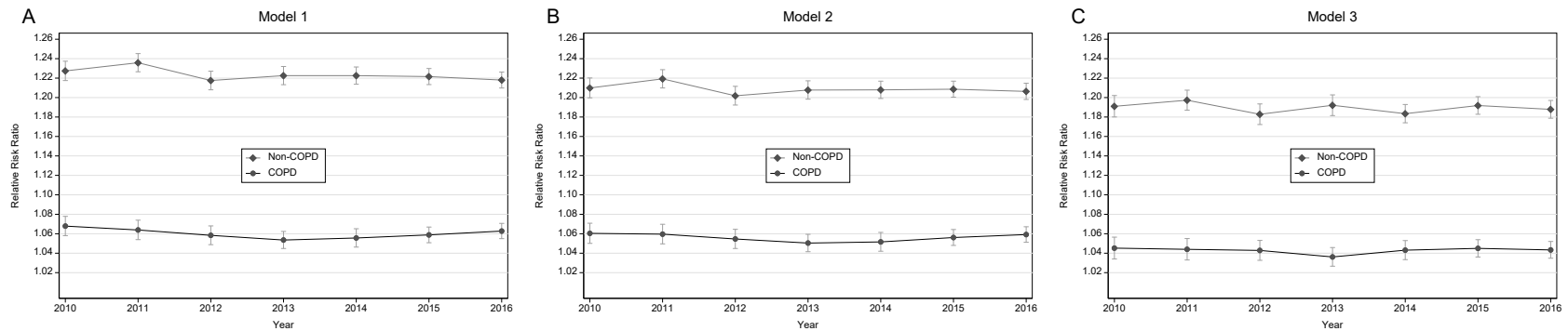
Appendix Figure 2: Estimates for the effect of the Elixhauser Comorbidity Index (scaled to ½ standard deviation, approximately a 7.5 point change) over time on the risk of Non-COPD and COPD readmission. Point estimates with 95% confidence intervals are presented.

Appendix Table 13: Multilevel multinomial Elixhauser coefficients (Odds Ratio with 95% CI) over time

	2010	2011	2012	2013	2014	2015	2016
Non-COPD returns							
Model 1	1.23 (1.22, 1.24)	1.24 (1.23, 1.25)	1.22 (1.21, 1.23)	1.22 (1.21, 1.23)	1.22 (1.21, 1.23)	1.22 (1.21, 1.23)	1.22 (1.21, 1.23)
Model 2	1.21 (1.20, 1.22)	1.22 (1.21, 1.23)	1.20 (1.19, 1.21)	1.21 (1.20, 1.22)	1.21 (1.20, 1.22)	1.21 (1.20, 1.22)	1.21 (1.20, 1.21)
Model 3	1.19 (1.18, 1.20)	1.20 (1.19, 1.21)	1.18 (1.17, 1.19)	1.19 (1.18, 1.20)	1.18 (1.17, 1.19)	1.19 (1.18, 1.20)	1.19 (1.18, 1.20)
COPD returns							
Model 1	1.07 (1.06, 1.08)	1.06 (1.05, 1.07)	1.06 (1.05, 1.07)	1.05 (1.04, 1.06)	1.06 (1.05, 1.07)	1.06 (1.05, 1.07)	1.06 (1.05, 1.07)
Model 2	1.06 (1.05, 1.07)	1.06 (1.05, 1.07)	1.05 (1.04, 1.06)	1.05 (1.04, 1.06)	1.05 (1.04, 1.06)	1.06 (1.05, 1.06)	1.06 (1.05, 1.07)
Model 3	1.05 (1.03, 1.06)	1.04 (1.03, 1.06)	1.04 (1.03, 1.05)	1.04 (1.03, 1.05)	1.04 (1.03, 1.05)	1.04 (1.04, 1.05)	1.04 (1.03, 1.05)

Appendix Table 14: Multilevel multinomial logistic regression models of readmission with expanded inclusion criteria of age ≥18 years) with hospital level random intercept

Model Info	Model 1		Model 2		Model 3	
N	1,682,629		1,679,169		1,677,941	
LL	-2,149,924.5		-2,136,418.5		-2,127,514.0	
df	5		43		81	
AIC	4,299,859.0		4,272,923.0		4,255,190.0	
BIC	4,299,920.5		4,273,453.0		4,256,189.0	
Predictors	**Non-COPD** *ref=Not Readmitted*	**COPD** *ref=Not Readmitted*	**Non-COPD** *ref=Not Readmitted*	**COPD** *ref=Not Readmitted*	**Non-COPD** *ref=Not Readmitted*	**COPD** *ref=Not Readmitted*
Elixhauser Index *(per 1/2 SD)*	*1.21 (1.21, 1.24)	*1.05 (1.05, 1.08)	*1.21 (1.21, 1.21)	*1.05 (1.05, 1.05)	*1.18 (1.18, 1.18)	*1.05 (1.05, 1.05)
Year *(ref=2010)*						
2011			0.98 (0.95, 1.01)	1.01 (0.98, 1.04)	0.98 (0.96, 1.01)	1.00 (0.97, 1.03)
2012			*0.94 (0.91, 0.97)	*0.97 (0.94, 1.00)	*0.94 (0.92, 0.97)	*0.96 (0.93, 0.99)
2013			*0.90 (0.87, 0.92)	*0.93 (0.90, 0.96)	*0.90 (0.88, 0.93)	*0.92 (0.90, 0.95)
2014			*0.88 (0.85, 0.90)	*0.91 (0.88, 0.93)	*0.86 (0.84, 0.88)	*0.92 (0.89, 0.95)
2015			*0.85 (0.83, 0.87)	*0.87 (0.84, 0.89)	*0.86 (0.84, 0.89)	*0.85 (0.82, 0.87)
2016			*0.84 (0.82, 0.87)	*0.88 (0.85, 0.90)	*0.85 (0.82, 0.87)	*0.86 (0.83, 0.88)
Quarter *(ref=1st)*						
2nd Quarter			*0.95 (0.94, 0.97)	*0.97 (0.96, 0.99)	*0.96 (0.94, 0.98)	*0.97 (0.96, 0.99)
3rd Quarter			*0.97 (0.95, 0.99)	*1.03 (1.01, 1.05)	*0.98 (0.96, 1.00)	*1.03 (1.01, 1.05)
4th Quarter			*0.95 (0.93, 0.97)	*1.02 (1.00, 1.04)	*0.96 (0.94, 0.97)	*1.02 (1.00, 1.04)
Sex *(ref=male)*						
Female			*0.94 (0.93, 0.95)	*0.92 (0.91, 0.94)	*0.92 (0.91, 0.93)	*0.91 (0.90, 0.93)
Age *(per 10 years)*			*1.09 (1.08, 1.10)	*0.92 (0.91, 0.93)	*1.05 (1.05, 1.06)	*0.91 (0.91, 0.92)
Income Quartile *(ref=1st)*						
2nd Quartile			1.00 (0.98, 1.02)	*0.97 (0.95, 0.99)	1.00 (0.98, 1.01)	*0.96 (0.95, 0.98)
3rd Quartile			1.00 (0.98, 1.01)	*0.96 (0.94, 0.98)	0.99 (0.97, 1.00)	*0.95 (0.93, 0.97)
4th Quartile			1.00 (0.98, 1.02)	*0.93 (0.91, 0.95)	0.98 (0.96, 1.00)	*0.91 (0.89, 0.93)
Missing			0.96 (0.91, 1.01)	0.99 (0.94, 1.05)	0.95 (0.90, 1.00)	0.99 (0.94, 1.05)
Payer *(ref=Medicare)*						
Medicaid			1.02 (0.99, 1.04)	*1.10 (1.08, 1.13)	*1.03 (1.00, 1.05)	*1.10 (1.08, 1.13)
Private			*0.74 (0.72, 0.75)	*0.65 (0.63, 0.67)	*0.75 (0.73, 0.77)	*0.66 (0.64, 0.68)
Self-Pay			*0.60 (0.57, 0.63)	*0.60 (0.58, 0.63)	*0.62 (0.59, 0.65)	*0.62 (0.59, 0.65)
Other/No Charge			*0.76 (0.72, 0.79)	*0.80 (0.77, 0.84)	*0.77 (0.74, 0.80)	*0.82 (0.78, 0.85)
Disposition *(ref=Routine to home)*						
Post-acute care					*1.36 (1.33, 1.38)	0.99 (0.97, 1.02)

Other	*1.20 (1.11, 1.28)	0.91 (0.83, 1.01)
Home Health	*1.31 (1.29, 1.34)	*1.29 (1.27, 1.31)
Length of stay *(per day)*	*1.02 (1.01, 1.02)	*1.01 (1.00, 1.01)
Care intensity *(ref=No)*		
Non-invasive ventilation	*0.89 (0.87, 0.91)	*1.38 (1.35, 1.41)
Mechanical ventilation	*0.78 (0.76, 0.81)	*0.87 (0.84, 0.91)
Tracheostomy	1.07 (1.00, 1.14)	1.01 (0.93, 1.11)
Cardiac arrest	*0.87 (0.77, 0.99)	*0.69 (0.58, 0.81)
CPR	1.14 (0.97, 1.33)	0.98 (0.80, 1.21)
Hospital ownership (ref=government)		
Private, non-profit	*0.97 (0.95, 0.99)	0.99 (0.96, 1.01)
Private, for-profit	*1.06 (1.03, 1.08)	1.01 (0.98, 1.04)
Hospital teaching status (ref=Non-teaching)		
Teaching Hospital	0.98 (0.97, 1.00)	1.02 (1.00, 1.04)
Hospital location (ref=Large metro area)		
Small metro area	*0.94 (0.92, 0.95)	*0.93 (0.91, 0.95)
Micropolitan area	*0.91 (0.88, 0.93)	*0.89 (0.87, 0.92)
Rural	*0.88 (0.85, 0.92)	*0.90 (0.86, 0.93)
Hospital Bed Size *(ref=Small)*		
Medium	1.01 (0.98, 1.03)	1.01 (0.98, 1.03)
Large	1.01 (0.99, 1.04)	1.00 (0.98, 1.03)
Annual Discharge (per 10k)	*1.02 (1.01, 1.04)	1.00 (0.99, 1.02)
Proportion Medicaid patient-days per 10%	*0.99 (0.98, 1.00)	*1.01 (1.00, 1.02)

Note: Odds Ratios with 95% Confidence Intervals Presented. * denotes p <0.05

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