NATIONAL QUALITY FORUM

Measure Submission and Evaluation Worksheet 5.0

This form contains the information submitted by measure developers/stewards, organized according to NQF's measure evaluation criteria and process. The evaluation criteria, evaluation guidance documents, and a blank online submission form are available on the submitting standards web page.

NQF #: 1893 NQF Project: Pulmonary Project
(for Endorsement Maintenance Review) Original Endorsement Date: Most Recent Endorsement Date:
BRIEF MEASURE INFORMATION
De.1 Measure Title: Hospital 30-Day, All-Cause, Risk-Standardized Mortality Rate (RSMR) following Chronic Obstructive Pulmonary Disease (COPD) Hospitalization
Co.1.1 Measure Steward: Centers for Medicare & Medicaid Services (CMS)
De.2 Brief Description of Measure: The measure estimates a hospital-level risk-standardized mortality rate (RSMR), defined as death from any cause within 30 days after the index admission date, for patients 18 and older discharged from the hospital with either a principal diagnosis of COPD or a principal diagnosis of respiratory failure with a secondary diagnosis of acute exacerbation of COPD.
2a1.1 Numerator Statement: The outcome for this measure is 30-day all-cause mortality. We define mortality as death from any cause within 30 days from the date of admission for patients 18 and older discharged from the hospital with either a principal diagnosis of COPD or a principal diagnosis of respiratory failure with a secondary diagnosis of acute exacerbation of COPD.
2a1.4 Denominator Statement: This claims-based measure can be used in either of two patient cohorts: (1) patients aged 65 years or older or (2) patients aged 18 years or older. We have explicitly tested the measure in both age groups. The cohort includes admissions for patients discharged from the hospital with either a principal diagnosis of COPD (see codes below) OR a principal diagnosis of respiratory failure (see codes below) WITH a secondary diagnosis of acute exacerbation of COPD (see codes below) and with a complete claims history for the 12 months prior to admission. If a patient has more than one COPD admission in a year, one hospitalization is randomly selected for inclusion in the measure.
2a1.8 Denominator Exclusions: An index admission is any eligible admission to an acute care hospital assessed in the measure for the outcome (died within 30 days after the index admission date). For all cohorts, the measure excludes admissions for patients: • transferred into the hospital from another acute care hospital (We assign the outcome for the acute episode of care to the first admitting hospital because the first hospital initiates patient management and is responsible for any decision to transfer the patient. Therefore, the first admission in an acute episode of care is eligible to be an index admission in the measure. The second or subsequent admissions in the same acute episode are excluded from the measure). • with inconsistent or unknown mortality status or other unreliable data (e.g. date of death precedes admission date). • who were discharged alive and against medical advice (AMA) (because providers did not have the opportunity to deliver full care and prepare the patient for discharge); For Medicare FFS patients, the measure additionally excludes admissions for patients: • enrolled in the Medicare Hospice program any time in the 12 months prior to the index hospitalization including the first day of the index admission (since it is likely these patients are continuing to seek comfort measures only). Although this exclusion currently applies to Medicare FFS patients, it could be expanded to include all-payer data if an acceptable method for identifying hospice patients outside of Medicare becomes available. Of note, a patient may satisfy multiple exclusion criteria.

1.1 Measure Type: Outcome
2a1. 25-26 Data Source: Administrative claims, Other
2a1.33 Level of Analysis: Facility

1.2-1.4 Is this measure paired with another measure? No

De.3 If included in a composite, please identify the composite measure (*title and NQF number if endorsed*):
This measure is not formally paired with another measure, however this measure is harmonized with a measure of hospital-level, all-cause, 30-day, risk-standardized readmission following a COPD hospitalization.

STAFF NOTES (*issues or questions regarding any criteria*)
Comments on Conditions for Consideration:
Is the measure untested? Yes☐ No☐ If untested, explain how it meets criteria for consideration for time-limited endorsement:
1a. Specific national health goal/priority identified by DHHS or NPP addressed by the measure (*check De.5*): 5. Similar/related endorsed or submitted measures (*check 5.1*): Other Criteria:
Staff Reviewer Name(s):

1. IMPACT, OPPORTUITY, EVIDENCE - IMPORTANCE TO MEASURE AND REPORT

Importance to Measure and Report is a threshold criterion that must be met in order to recommend a measure for endorsement. All three subcriteria must be met to pass this criterion. See guidance on evidence.
Measures must be judged to be important to measure and report in order to be evaluated against the remaining criteria. (evaluation criteria)

1a. High Impact: H☐ M☐ L☐ I ☐
(*The measure directly addresses a specific national health goal/priority identified by DHHS or NPP, or some other high impact aspect of healthcare.*)

De.4 Subject/Topic Areas *(Check all the areas that apply)*: Pulmonary/Critical Care, Pulmonary/Critical Care : Chronic Obstructive Pulmonary Disease (COPD), Pulmonary/Critical Care : Dyspnea
De.5 Cross Cutting Areas (*Check all the areas that apply)*: Care Coordination, Population Health, Safety : Complications, Safety : Healthcare Associated Infections

1a.1 Demonstrated High Impact Aspect of Healthcare: Affects large numbers, A leading cause of morbidity/mortality, High resource use, Patient/societal consequences of poor quality, Severity of illness

1a.2 If "Other," please describe:

1a.3 Summary of Evidence of High Impact *(Provide epidemiologic or resource use data)*:
Affects Large Numbers
COPD is a priority condition for outcomes measure development because it is a leading cause of mortality and morbidity. COPD affects as many as 24 million individuals in the United States and is the nation's 4th leading cause of death.1,2 Between 1998 and 2008 the number of patients hospitalized annually for acute exacerbations of COPD increased by approximately 18%.3
High Costs
In 2008 COPD was one of the top 20 most expensive conditions treated in U.S. hospitals.3 It was also one of the top 20 most expensive conditions billed to Medicare, accounting for nearly $17 billion of total hospital charges billed to Medicare.3

1a.4 Citations for Evidence of High Impact cited in 1a.3: 1. National Heart, Lung, and Blood Institute. Morbidity & Mortality: Chart Book on Cardiovascular, Lung, and Blood Diseases. 2009. http://www.nhlbi.nih.gov/resources/docs/2009_ChartBook.pdf . Accessed March 23, 2011.

2. The Centers for Disease Control and Prevention. National Center for Health Statistics Chronic Lower Respiratory Disease. FastStats 2010; http://www.cdc.gov/nchs/fastats/copd.htm . Accessed September 18, 2010.
3. Agency for Healthcare Research and Quality. Healthcare Cost and Utilization Project (HCUP). The National Hospital Bill: The Most Expensive Conditions by Payer, 2008. March 2011 http://www.hcup-us.ahrq.gov/reports/statbriefs/sb107.pdf . Accessed March 23, 2011.

1b. Opportunity for Improvement: H☐ M☐ L☐ I ☐
(*There is a demonstrated performance gap - variability or overall less than optimal performance*)

1b.1 Briefly explain the benefits (improvements in quality) envisioned by use of this measure:
COPD is currently the 4th leading cause of death in the US1 and projected care costs for direct and indirect health care expenditures were nearly $50 billion for 2010. 2 Studies report that in-hospital mortality rates for patients hospitalized for exacerbations of COPD range from 2-5% 3-7 and 30-day mortality rates range from 3-9%. 8-9

Mortality rates from our 2008 data among Medicare fee-for-service patients are consistent with those reported in the literature (for all patients), with crude 30-day mortality rates ranging from 2.78%-14.3% (10th and 90th percentile, respectively). Given the range in mortality rates across hospitals, this measure may create incentives for hospitals to focus quality improvement efforts on reducing mortality rates for patients hospitalized with an acute exacerbation of COPD, particularly among patients at high risk for complications, such as those requiring mechanical ventilation (or treated in intensive care units).

In analyses of Medicare Part A inpatient claims data (2008) the mean and median risk standardized 30-day mortality rate for patients admitted with an acute exacerbation of COPD are 8.6% and 8.5% respectively. There is a substantial variation across hospitals, with risk standardized rates ranging from 7.6% in the 10th percentile to 9.9% in the 90th percentile. These findings suggest there is variation in the quality of care provided to COPD patients and that improvements in care may be correlated with improved patient outcomes and quality of care.

References:

1.The Centers for Disease Control and Prevention. National Center for Health Statistics Chronic Lower Respiratory Disease. FastStats 2010; http://www.cdc.gov/nchs/fastats/copd.htm . Accessed September 18, 2010.

2. National Heart, Lunch, and Blood Institute, The Morbidity & Mortality: Chart Book on Cardiovascular, Lung, and Blood Disease, 2009. http://www.nhlbi.nih.gov/resources/docs/2009_ChartBook.pdf . Accessed March 23, 2011.

3. Agency for Healthcare Research and Quality. Healthcare Cost and Utilization Project. Statistics on Hospital Stays http://hcupnet.ahrq.gov . Accessed September 18, 2010.

4. Patil SP, Krishnan JA, Lechtzin n, Diette GB. In-hospital mortality following acute exacerbations of chronic obstructive pulmonary disease. Archives of Internal Medicine. Sep 28 2009; 169 (17): 1595-1602.

5. Tabak YP, Sun X, Johannes RS, et al. Mortality and need for mechanical ventilation in acute exacerbations of chronic obstructive pulmonary disease: development and validation of simple risk score. Archives of Internal Medicine. Sep 28 2009; 169 (17): 1595-1602.

6. Lindenauer PK, Pekow P, Gao S, et al. Quality of care for patients hospitalized for acute exacerbations of chronic obstructive pulmonary disease. Ann Intern Med. June 20 2006; 144 (12): 894-903.

7. Dransfield MT, Rowe SM, Johnson JE, et al. Use of beta blockers and the risk of death in hospitalized patients with acute exacerbations of COPD. Thorax. Apr 2008; 63 (4): 301-305.

8. Faustini A, Marino C, D'Ippoliti D, et al. The Impact on risk-factor analysis of different mortality outcomes in COPD patients. European Respiratory Journal. Sep 2008; 32 (3): 629-636.

9. Fruchter O, Yigla M., Predictors of long-term survival in elderly patients hospitalized for acute exacerbations of chronic

obstructive pulmonary disease. Respirology. Nov 2008; 13 (6): 851-855.

1b.2 Summary of Data Demonstrating Performance Gap *(Variation or overall less than optimal performance across providers)*: [*For Maintenance – Descriptive statistics for performance results for this measure - distribution of scores for measured entities by quartile/decile, mean, median, SD, min, max, etc.*]
There is a paucity of research on quality and outcomes for COPD patients in the US. A large study of nearly 70,000 patients in 360 US hospitals demonstrated widespread variation in practice patterns across institutions1, including underuse of antibiotics and systemic corticosteroids, suggesting there are opportunities to improve quality of care.

A review of the medical records of 409 Medicare Beneficiaries in Oklahoma reported similar opportunities to improve adherence to recommendations contained in clinical guidelines, especially with regard to use systemic corticosteroids.2

A third study, of 169 patients in 12 US communities, documented substantial opportunities to improve the quality of both chronic and acute care to patients with COPD. COPD patients received 58.0% of recommended care including 60.4% of acute care and 46.1% of routine care.3

Finally, in a study using data from the Agency for Healthcare Research and Quality's Nationwide Inpatient Sample, investigators observed substantial variation in mortality rates associated with region, hospital type and hospital teaching status.4

1b.3 Citations for Data on Performance Gap: [*For Maintenance – Description of the data or sample for measure results reported in 1b.2 including number of measured entities; number of patients; dates of data; if a sample, characteristics of the entities included*]
1. Lindenauer PK, Pekow P, Gao S, et al. Quality of care for patients hospitalized for acute exacerbations of chronic obstructive pulmonary disease. Ann Intern Med. Jun 20 2006; 114 (12): 894-903.
2. Bratzler DW, Oehlert WH, McAdams LM, et al. Management of acute exacerbations of chronic obstructive pulmonary disease in elderly: physician practices in the community hospital setting. J Okla State Med Assoc. 204; 97: 227-32.
3. Mularski RA, Asch SM, Shrank WH, et al. The quality of obstructive lung disease care for adults in the United States: Adherence to recommended processes. Chest 2006; 130: 1844-1850.
4. Patil SP, Krishnan JA, Lechtzin N, Diette GB. In-hospital mortality following acute exacerbations of chronic obstructive pulmonary disease. Archives of Internal medicine. May 26 2003; 163 (10): 1180-1186.

1b.4 Summary of Data on Disparities by Population Group: [*For Maintenance –Descriptive statistics for performance results for this measure by population group*]
A study of nearly 70,000 patients hospitalized for acute exacerbation of COPD, in which 9% of patients were black and 3% were Hispanic, reported that black and Hispanic patients were less likely than white patients to receive recommended and ideal care.1

A study by Mularski, et al., demonstrated modest variation in recommended care provided between racial groups, geographic areas, insurance types, and other characteristics. 2

We conducted analyses to explore disparities in hospitals' performance on the measure by race and socioeconomic status (SES).

Race
We used the Medicare Provider Analysis and Review (MEDPAR) File for 2008 to calculate the percentage of African-American patients at each hospital, using all patients admitted to each hospital. We examined hospital-level RSMRs across hospitals which were grouped by decile of percentage of African-American patients they cared for. There were no differences in the RSMRs by decile. The distributions for the RSMRs overlapped, and some hospitals caring for the highest percentage of African-American patients performed well on the measure. The median RSMR for hospitals with the highest percentage of African-American patients was 8.4% compared with 8.5% for hospitals with the lowest percentage of African-American patients. In comparison to the national average, hospitals with high proportions of African-American patients do not have worse 30-day RSMRs.

SES
We determined a SES level for each hospital, based on the median household income for the hospital zip code. We used 2000 census data (http://factfinder.census.gov/home/saff/main.html?_lang=en)
to identify hospital five-digit zip codes and median household income. We categorized median household income into deciles and

examined hospital-level RSMRs across deciles of median household income. There were no differences in RSMRs across income decile. The distributions for the RSMRs overlapped, and many hospitals in the lowest median income decile performed well on the measure. The median RSMR was 8.5% for hospitals in the lowest and highest deciles of median household income. In comparison to the national average, hospitals in low-income zip codes do not have worse 30-day RSMRs.

1b.5 Citations for Data on Disparities Cited in 1b.4: [*For Maintenance – Description of the data or sample for measure results reported in 1b.4 including number of measured entities; number of patients; dates of data; if a sample, characteristics of the entities included*]

1. Lindenauer PK, Pekow P, Gao S, et al. Quality of care for patients hospitalized for acute exacerbations of chronic obstructive pulmonary disease. Ann Intern Med. Jun 20 2006; 114 (12) 894-903.
2. Mularski RA. Asch SM, Shrank WH, et al. The quality of obstructive lung disease care for adults in the United States: Adherence to recommended process. Chest 2006; 130-1844-1850.

1c. Evidence (*Measure focus is a health outcome OR meets the criteria for quantity, quality, consistency of the body of evidence.*)
Is the measure focus a health outcome? Yes☐ No☐ If not a health outcome, rate the body of evidence.

Quantity: H☐ M☐ L☐ I☐ Quality: H☐ M☐ L☐ I☐ Consistency: H☐ M☐ L☐ I☐

Quantity	Quality	Consistency	Does the measure pass subcriterion1c?
M-H	M-H	M-H	Yes☐
L	M-H	M	Yes☐ IF additional research unlikely to change conclusion that benefits to patients outweigh harms: otherwise No☐
M-H	L	M-H	Yes☐ IF potential benefits to patients clearly outweigh potential harms: otherwise No☐
L-M-H	L-M-H	L	No ☐

Health outcome – rationale supports relationship to at least one healthcare structure, process, intervention, or service	Does the measure pass subcriterion1c? Yes☐ IF rationale supports relationship

1c.1 Structure-Process-Outcome Relationship *(Briefly state the measure focus, e.g., health outcome, intermediate clinical outcome, process, structure; then identify the appropriate links, e.g., structure-process-health outcome; process- health outcome; intermediate clinical outcome-health outcome)*:
N/A This is an outcomes measure, not a process measure.

1c.2-3 Type of Evidence *(Check all that apply)*:

1c.4 Directness of Evidence to the Specified Measure *(State the central topic, population, and outcomes addressed in the body of evidence and identify any differences from the measure focus and measure target population)*:
N/A This is an outcomes measure, not a process measure.

1c.5 Quantity of Studies in the Body of Evidence *(Total number of studies, not articles)*: N/A This is an outcomes measure, not a process measure.

1c.6 Quality of Body of Evidence (*Summarize the certainty or confidence in the estimates of benefits and harms to patients across studies in the body of evidence resulting from study factors. Please address: a) study design/flaws; b) directness/indirectness of the evidence to this measure (e.g., interventions, comparisons, outcomes assessed, population included in the evidence); and c) imprecision/wide confidence intervals due to few patients or events*): N/A This is an outcomes measure, not a process measure.

1c.7 Consistency of Results across Studies *(Summarize the consistency of the magnitude and direction of the effect):* N/A This is an outcomes measure, not a process measure.

1c.8 Net Benefit *(Provide estimates of effect for benefit/outcome; identify harms addressed and estimates of effect; and net benefit - benefit over harms)*:
N/A This is an outcomes measure, not a process measure.

1c.9 Grading of Strength/Quality of the Body of Evidence. Has the body of evidence been graded? No

1c.10 If body of evidence graded, identify the entity that graded the evidence including balance of representation and any disclosures regarding bias: N/A This is an outcomes measure, not a process measure.

1c.11 System Used for Grading the Body of Evidence: Other

1c.12 If other, identify and describe the grading scale with definitions: N/A This is an outcomes measure, not a process measure.

1c.13 Grade Assigned to the Body of Evidence: N/A This is an outcomes measure, not a process measure.

1c.14 Summary of Controversy/Contradictory Evidence: N/A This is an outcomes measure, not a process measure.

1c.15 Citations for Evidence other than Guidelines*(Guidelines addressed below)*:
N/A This is an outcomes measure, not a process measure.

1c.16 Quote verbatim, the specific guideline recommendation *(Including guideline # and/or page #)*:
N/A This is an outcomes measure, not a process measure.

1c.17 Clinical Practice Guideline Citation: N/A This is an outcomes measure, not a process measure.

1c.18 National Guideline Clearinghouse or other URL: N/A This is an outcomes measure, not a process measure.

1c.19 Grading of Strength of Guideline Recommendation. Has the recommendation been graded? No

1c.20 If guideline recommendation graded, identify the entity that graded the evidence including balance of representation and any disclosures regarding bias:

1c.21 System Used for Grading the Strength of Guideline Recommendation: Other

1c.22 If other, identify and describe the grading scale with definitions: N/A This is an outcomes measure, not a process measure.

1c.23 Grade Assigned to the Recommendation: N/A This is an outcomes measure, not a process measure.

1c.24 Rationale for Using this Guideline Over Others: N/A This is an outcomes measure, not a process measure.

Based on the NQF descriptions for rating the evidence, what was the developer's assessment of the quantity, quality, and consistency of the body of evidence?
1c.25 Quantity: High 1c.26 Quality: High1c.27 Consistency: High

Was the threshold criterion, *Importance to Measure and Report*, met?
(*1a & 1b must be rated moderate or high and 1c yes*) Yes☐ No☐
Provide rationale based on specific subcriteria:

For a new measure if the Committee votes NO, then STOP.
For a measure undergoing endorsement maintenance, if the Committee votes NO because of 1b. (no opportunity for improvement), it may be considered for continued endorsement and all criteria need to be evaluated.

2. RELIABILITY & VALIDITY - SCIENTIFIC ACCEPTABILITY OF MEASURE PROPERTIES

Extent to which the measure, as specified, produces consistent (reliable) and credible (valid) results about the quality of care when implemented. (evaluation criteria)
Measure testing must demonstrate adequate reliability and validity in order to be recommended for endorsement. Testing may be conducted for data elements and/or the computed measure score. Testing information and results should be entered in the appropriate field. Supplemental materials may be referenced or attached in item 2.1. See guidance on measure testing.

S.1 Measure Web Page *(In the future, NQF will require measure stewards to provide a URL link to a web page where current detailed specifications can be obtained*). Do you have a web page where current detailed specifications for this measure can be obtained? No

S.2 If yes, provide web page URL:

2a. RELIABILITY. Precise Specifications and Reliability Testing: H☐ M☐ L☐ I ☐

2a1. Precise Measure Specifications. (*The measure specifications precise and unambiguous.*)

2a1.1 Numerator Statement *(Brief, narrative description of the measure focus or what is being measured about the target population, e.g., cases from the target population with the target process, condition, event, or outcome)*:
The outcome for this measure is 30-day all-cause mortality. We define mortality as death from any cause within 30 days from the date of admission for patients 18 and older discharged from the hospital with either a principal diagnosis of COPD or a principal diagnosis of respiratory failure with a secondary diagnosis of acute exacerbation of COPD.

2a1.2 Numerator Time Window *(The time period in which the target process, condition, event, or outcome is eligible for inclusion)*:
Patients who die within 30 days of the index admission date.

2a1.3 Numerator Details *(All information required to identify and calculate the cases from the target population with the target process, condition, event, or outcome such as definitions, codes with descriptors, and/or specific data collection items/responses*:
This outcome measure does not have a traditional numerator and denominator like a core process measure (e.g., percentage of adult patients with diabetes aged 18-75 years receiving one or more hemoglobin A1c tests per year); thus, we are using this field to define the outcome.

Measure includes deaths from any cause within 30 days from admission date of the index hospitalization.

Identifying deaths in the FFS measure
As currently reported, we identify deaths for FFS Medicare patients 65 years and older in the Medicare Enrollment Database.

Identifying deaths in the all-payer measure
For the purposes of development deaths were identified using the California vital statistics data file. Nationally, post-discharge deaths can be identified using an external source of vital status, such as the Social Security Administration's Death Master File (DMF) or the Centers for Disease Control and Prevention's National Death Index (NDI).

2a1.4 Denominator Statement *(Brief, narrative description of the target population being measured)*:
This claims-based measure can be used in either of two patient cohorts: (1) patients aged 65 years or older or (2) patients aged 18 years or older. We have explicitly tested the measure in both age groups.

The cohort includes admissions for patients discharged from the hospital with either a principal diagnosis of COPD (see codes below) OR a principal diagnosis of respiratory failure (see codes below) WITH a secondary diagnosis of acute exacerbation of COPD (see codes below) and with a complete claims history for the 12 months prior to admission.

If a patient has more than one COPD admission in a year, one hospitalization is randomly selected for inclusion in the measure.

2a1.5 Target Population Category *(Check all the populations for which the measure is specified and tested if any)*: Adult/Elderly Care, Populations at Risk

2a1.6 Denominator Time Window *(The time period in which cases are eligible for inclusion)*:
This measure was developed with 12 months of data.

2a1.7 Denominator Details (*All information required to identify and calculate the target population/denominator such as definitions, codes with descriptors, and/or specific data collection items/responses)*:
Note: This outcome measure does not have a traditional numerator and denominator like a core process measure (e.g., percentage of adult patients with diabetes aged 18-75 years receiving one or more hemoglobin A1c tests per year). We therefore use this field to define the measure cohort.

The denominator includes patients 18 and over hospitalized for COPD. The measure was developed in a cohort of patients 65 years and older who were enrolled in Medicare FFS and admitted to non-federal hospitals. To be included in the Medicare FFS cohort the inclusion criteria required that the patient be continuously enrolled in Medicare FFS Parts A and B for the 12 months prior to the index hospitalization.

Primary COPD and respiratory failure with a secondary diagnosis of acute exacerbation of COPD are defined by the following ICD-9-CM and ICD-10-CM codes:

ICD-9-CM codes used to define COPD:
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): not otherwise specified, 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.

ICD-10-CM codes used to define COPD:
J441 Chronic obstructive pulmonary disease with (acute) exacerbation
J418 Mixed simple and mucopurulent chronic bronchitis
J42 Unspecified chronic bronchitis
J439 Emphysema, unspecified
J449 Chronic obstructive pulmonary disease, unspecified
J440 Chronic obstructive pulmonary disease with acute low respiratory infection

ICD-9-CM codes used to define respiratory failure:
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 and chronic respiratory failure.
799.1 Other ill-defined and unknown causes of morbidity and mortality; respiratory arrest, cardiorespiratory failure

ICD-9-CM codes used to define acute exacerbation of COPD:
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
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

ICD-10-CM codes used to define respiratory failure:

J9600 Respiratory failure, unspecified, unspecified whether with hypoxia or hypercapnia
J9690 Respiratory failure, unspecified, unspecified whether with hypoxia or hypercapnia
J80 Acute Respiratory distress syndrome
J9620 Acute and chronic respiratory failure, unspecified whether the hypoxia or hypercapnia
R092 Respiratory arrest

ICD-10-CM codes used to define acute exacerbation of COPD:
J441 Chronic obstructive pulmonary disease with (acute) exacerbation
J440 Chronic obstructive pulmonary disease with acute low respiratory infection

2a1.8 Denominator Exclusions *(Brief narrative description of exclusions from the target population)*:
An index admission is any eligible admission to an acute care hospital assessed in the measure for the outcome (died within 30 days after the index admission date).
For all cohorts, the measure excludes admissions for patients:
• transferred into the hospital from another acute care hospital (We assign the outcome for the acute episode of care to the first admitting hospital because the first hospital initiates patient management and is responsible for any decision to transfer the patient. Therefore, the first admission in an acute episode of care is eligible to be an index admission in the measure. The second or subsequent admissions in the same acute episode are excluded from the measure).
• with inconsistent or unknown mortality status or other unreliable data (e.g. date of death precedes admission date).
• who were discharged alive and against medical advice (AMA) (because providers did not have the opportunity to deliver full care and prepare the patient for discharge);

For Medicare FFS patients, the measure additionally excludes admissions for patients:
• enrolled in the Medicare Hospice program any time in the 12 months prior to the index hospitalization including the first day of the index admission (since it is likely these patients are continuing to seek comfort measures only). Although this exclusion currently applies to Medicare FFS patients, it could be expanded to include all-payer data if an acceptable method for identifying hospice patients outside of Medicare becomes available.

Of note, a patient may satisfy multiple exclusion criteria.

2a1.9 Denominator Exclusion Details *(All information required to identify and calculate exclusions from the denominator such as definitions, codes with descriptors, and/or specific data collection items/responses)*:
We provide denominator exclusion details for the Medicare data. The specific fields used in "all-payer" data will vary.
Transfers to other acute care facilities are identified in the claims when a patient with an inpatient hospital admission (with at least one qualifying COPD admission) is discharged from an acute care hospital and admitted to another acute care hospital on the same day or next day.
Inconsistent vital status or unreliable data are identified if any of the following conditions are met 1) the patient's age is greater than 115 years: 2) if the discharge date for a hospitalization is before the admission date; 3) if the patient has a sex other than 'male' or 'female'.
Discharges Against Medical Advice (AMA) are identified using the discharge disposition indicator.
Hospice enrollment in the 12 months prior to or on the index admission is identified using enrollment status derived from the EDB and the Inpatient SAF (this exclusion applies when the measure is used in Medicare FFS patients only).

2a1.10 Stratification Details/Variables *(All information required to stratify the measure results including the stratification variables, codes with descriptors, definitions, and/or specific data collection items/responses)*:
Results of this measure will not be stratified.

2a1.11 Risk Adjustment Type *(Select type. Provide specifications for risk stratification in 2a1.10 and for statistical model in 2a1.13)*: Statistical risk model 2a1.12 If "Other," please describe:

2a1.13 Statistical Risk Model and Variables *(Name the statistical method - e.g., logistic regression and list all the risk factor variables. Note - risk model development should be addressed in 2b4.)*:
Our approach to risk adjustment was tailored to and appropriate for a publicly reported outcome measure, as articulated in the American Heart Association (AHA) Scientific Statement, "Standards for Statistical Models Used for Public Reporting of Health

Outcomes".1

The measure employs a hierarchical logistic regression model to create a hospital-level 30-day RSMR. This approach to modeling appropriately accounts for the structure of the data (patients clustered within hospitals), the underlying risk due to patients' comorbidities, and sample size at a given hospital when estimating hospital mortality rates. In brief, the approach simultaneously models two levels (patient and hospital) to account for the variance in patient outcomes within and between hospitals.2 At the patient level the model adjusts the log-odds of mortality within 30 days of admission for age and selected clinical covariates. The second level models hospital-specific intercepts as arising from a normal distribution. The hospital-specific intercept represents the hospital contribution to the risk of mortality, after accounting for patient risk and sample size, and can be inferred as a measure of quality. The hospital-specific intercepts are given a distribution in order to account for the clustering (non-independence) of patients within the same hospital. If there were no differences among hospitals, then after adjusting for patient risk, the hospital intercepts should be identical across all hospitals.

The RSMR is calculated as the ratio of the number of "predicted" to the number of "expected" deaths, multiplied by the national unadjusted mortality rate. For each hospital, the numerator of the ratio ("predicted") is the number of deaths within 30 days predicted on the basis of the hospital's performance with its observed case mix, and the denominator ("expected") is the number of deaths expected on the basis of the nation's performance with that hospital's case mix. This approach is analogous to a ratio of "observed" to "expected" used in other types of statistical analyses. It conceptually allows for a comparison of a particular hospital's performance given its case-mix to an average hospital's performance with the same case-mix. Thus, a lower ratio indicates lower-than-expected mortality or better quality and a higher ratio indicates higher-than-expected mortality or worse quality.

The predicted hospital outcome (the numerator) is the sum of predicted probabilities of death for all patients at a particular hospital. The predicted probability of each patient in that hospital is calculated using the hospital-specific intercept and patient risk factors. The expected number of deaths (the denominator) is the sum of expected probabilities of death for all patients at a hospital. The expected probability of each patient in a hospital is calculated using a common intercept and patient risk factors.
Candidate and Final Risk-adjustment Variables: The measure was developed using Medicare FFS claims data. Candidate variables were patient-level risk adjustors that were expected to be predictive of mortality, based on empirical analysis, prior literature, and clinical judgment, including age and indicators of comorbidity and disease severity. For each patient, covariates are obtained from Medicare claims extending 12 months prior to and including the index admission. The model adjusts for case mix differences based on the clinical status of patients at the time of admission. We used condition categories (CCs), which are clinically meaningful groupings of more than 15,000 ICD-9-CM diagnosis codes, and combinations of CCs as candidate variables. A file which contains a list of the ICD-9-CM codes and their groupings into CCs is available on www.qualitynet.org (http://www.qualitynet.org/dcs/ContentServer?c=Page&pagename=QnetPublic%2FPage%2FQnetTier3&cid=1182785083979). We did not risk-adjust for CCs that were possible adverse events of care and that were only recorded in the index admission. Only comorbidities that conveyed information about the patient at that time or in the 12 months prior, and not complications that arose during the course of the hospitalization were included in the risk-adjustment.

References:
1. Krumholz HM, Brindis RG, Brush JE, et al. 2006. Standards for Statistical Models Used for Public Reporting of Health Outcomes: An American Heart Association Scientific Statement From the Quality of Care and Outcomes Research Interdisciplinary Writing Group: Cosponsored by the Council on Epidemiology and Prevention and the Stroke Council Endorsed by the American College of Cardiology Foundation. Circulation 113: 456-462.

2. Normand S-LT, Shahian DM. 2007. Statistical and Clinical Aspects of Hospital Outcomes Profiling. Stat Sci 22 (2): 206-226.

Frequencies and odds ratios for the model development sample (2008 Medicare FFS patients aged 65 and older; n=150,035 admissions) are presented below.

Table 1: Final set of risk-adjustment variables:

Variable//Frequency (%)//Odds Ratio (95% confidence interval)

Demographic

• Age-65 (years above 65, continuous) for 65 and over cohorts/Frequency = -/OR (95% CI)=1.03 (1.03-1.04); (this variable is Age (years, continuous) for 18 and over cohorts)

Cardiovascular/Respiratory
• Sleep Apnea (ICD-9 CM diagnosis codes: 327.20, 327.21, 327.23, 327.27, 327.29, 780.51, 780.53, 780.57)/Frequency=9.6/OR (95% CI)=0.87 (0.81-0.94)
• History of mechanical ventilation (ICD-9 procedure codes: 93.90, 96.70, 96.71, 96.72)/ Frequency= 6.0/OR (95% CI)=1.19 (1.11-1.28)
• Respirator dependence/respiratory failure (CC 77-78)/ Frequency=1.2/OR (95% CI)=0.88 (0.76-1.02)
• Cardio-respiratory failure and shock (CC 79)/ Frequency=26.4/OR (95% CI)=1.60 (1.53-1.68)
• Congestive heart failure (CC 80)/ Frequency=41.5/OR (95% CI)=1.33 (1.28-1.40)
• Chronic atherosclerosis (CC 83-84)/Frequency=50.4/OR (95% CI)=0.87 (0.83-0.90)
• Arrhythmias (CC 92-93)/ Frequency=37.2/OR (95% CI)=1.17 (1.12-1.22)
• Vascular or circulatory disease (CC 104-106)/ Frequency=38.2/OR (95% CI)=1.09 (1.05-1.14)
• Fibrosis of lung and other chronic lung disorder (CC 109)/Frequency=17.0/OR (95% CI)=1.08 (1.03-1.13)
• Asthma (CC 110)/ Frequency=17.1/OR (95% CI)=0.67 (0.63-0.71)
• Pneumonia (CC 111-113)/ Frequency=49.5/OR (95 CI)=1.29 (1.24-1.35)
• Pleural effusion/Pneumothorax (CC 114)/ Frequency=11.8/OR (95% CI)=1.17 (1.11-1.23)
• Other lung disorders (CC 115)/ Frequency=53.1/OR (95% CI)=0.80 (0.77-0.83)

Other Comorbid Conditions
• Metastatic cancer and acute leukemia (CC 7)/ Frequency=2.8/OR (95% CI)=2.34 (2.13-2.56)
• Lung, upper digestive tract, and other severe cancers (CC 8)/ Frequency=6.0/OR (95% CI)=1.80 (1.67-1.92)
• Lymphatic, head and neck, brain, and other major cancers; breast, prostate, colorectal and other cancers and tumors; other respiratory and heart neoplasms (CC 9-11)/ Frequency=14.1/OR (95% CI)=1.03 (0.97-1.08)
• Other digestive and urinary neoplasms (CC 12)/ Frequency=6.9/OR (95% CI)=0.91 (0.84-0.98)
• Diabetes and DM complications (CC 15-20, 119-120)/ Frequency=38.3/OR (95% CI)=0.91 (0.87-0.94)
• Protein-calorie malnutrition (CC 21)/ Frequency=7.4/OR (95% CI)=2.17 (2.05-2.29)
• Disorders of Fluid/Electrolyte/Acid-Base (CC 22-23)/ Frequency=32.1/OR (95% CI)=1.13 (1.08-1.18)
• Other Endocrine/Metabolic/Nutritional Disorders (CC 24)/ Frequency=68.0/OR (95% CI)=0.75 (0.72-0.78)
• Other Gastrointestinal Disorders (CC 36)/Frequency=56.2/OR (95% CI)=0.81 (0.78-0.84)
• Osteoarthritis of Hip or Knee (CC 40)/ Frequency=9.3/OR (95% CI)=0.74 (0.69-0.80)
• Other Musculoskeletal and Connective Tissue Disorders (CC 43)/ Frequency=64.1/OR (95% CI)=0.83 (0.79-0.86)
• Iron Deficiency and Other/Unspecified Anemias and Blood Disease (CC 47)/ Frequency=40.8/OR (95% CI)=1.08 (1.04-1.12)
• Dementia and senility (CC 49-50)/ Frequency=17.1/OR (95% CI)=1.09 (1.04-1.14)
• Drug/Alcohol Abuse, Without Dependence (CC 53)/ Frequency=23.5/OR (95% CI)=0.79 (0.75-0.83)
• Other Psychiatric Disorders (CC 60)/ Frequency=16.5/OR (95% CI)=1.12 (1.07-1.18)
• Quadriplegia, paraplegia, functional disability (CC 67-69, 100-102, 177-178)/ Frequency=4.9/OR (95% CI)=1.03 (0.95-1.12)
• Mononeuropathy, Other Neurological Conditions/Injuries (CC 76)/ Frequency=11.4/OR 95% CI)=0.85 (0.80-0.91)
• Hypertension and Hypertensive Disease (CC 90-91)/ Frequency=80.4/OR (95% CI)=0.78 (0.75-0.82)
• Stroke (CC 95-96)/ Frequency=6.8/OR (95% CI)=1.00 (0.93-1.08)
• Retinal Disorders, Except Detachment and vascular Retinopathies (CC 121)/ Frequency=10.8/OR (95% CI)=0.87 (0.82-0.93)
• Other Eye Disorders (CC 124)/ Frequency=19.1/OR (95% CI)=0.90 (0.86-0.95)
• Other Ear, Nose, Throat, and Mouth Disorders (CC 127)/Frequency=35.2/OR (95% CI)=0.83 (0.80-0.87)
• Renal Failure (CC 131)/ Frequency=17.9/OR (95% CI)=1.12 (1.07-1.18)
• Decubitus ulcer or chronic skin ulcer (CC 148-149)/ Frequency=7.4/OR (95% CI)1.27 (1.19-1.35)
• Other Dermatological Disorders (CC 153)/ Frequency=28.5/OR (95% CI)0.91 (0.87-0.95)
• Trauma (CC 154-156, 158-161)/ Frequency=9.0/OR (95% CI)1.10 (1.03-1.16)
• Vertebral Fractures (CC 157)/ Frequency=5.0/OR (95% CI)=1.33 (1.24-1.44)
• Major Complications of Medical Care and Trauma (CC 164)/ Frequency=5.5/OR (95% CI)=0.81 (0.75-0.88)

ICD-10-CM codes for model variables (for those variables defined by ICD-9 CM codes rather than CCs)
Mechanical Ventilation

• 5A09357 Assistance with Respiratory Ventilation, Less than 24 Consecutive Hours, Continuous Positive Airway Pressure
• 5A09457 Assistance with Respiratory Ventilation, 24-96 Consecutive Hours, Continuous Positive Airway Pressure
• 5A09557 Assistance with Respiratory Ventilation, Greater than 96 Consecutive Hours, Continuous Positive Airway Pressure
• 5A1935Z Respiratory Ventilation, Less than 24 Consecutive Hours
• 5A1945Z Respiratory Ventilation, 24-96 Consecutive Hours•5A1955Z Respiratory Ventilation, Greater than 96 Consecutive Hours
Sleep Apnea
• G4730 Sleep apnea, unspecified
• G4731 Primary central sleep apnea
• G4733 Obstructive sleep apnea (adult) (pediatric)
• G4737 Central sleep apnea in conditions classified elsewhere
• G4739 Other sleep apnea

2a1.14-16 Detailed Risk Model Available at Web page URL (or attachment). Include coefficients, equations, codes with descriptors, definitions, and/or specific data collection items/responses. Attach documents only if they are not available on a webpage and keep attached file to 5 MB or less. NQF strongly prefers you make documents available at a Web page URL. Please supply login/password if needed:
Attachment
Del49a_COPD_MortalityMethodologyReport_11 04 11 FINAL.pdf

2a1.17-18. Type of Score: Rate/proportion

2a1.19 Interpretation of Score *(Classifies interpretation of score according to whether better quality is associated with a higher score, a lower score, a score falling within a defined interval, or a passing score)*: Better quality = Lower score

2a1.20 Calculation Algorithm/Measure Logic*(Describe the calculation of the measure score as an ordered sequence of steps including identifying the target population; exclusions; cases meeting the target process, condition, event, or outcome; aggregating data; risk adjustment; etc.)*:
The RSMR is calculated as the ratio of the number of "predicted" to the number of "expected" deaths, multiplied by the national unadjusted mortality rate. For each hospital, the numerator of the ratio ("predicted") is the number of deaths within 30 days predicted on the basis of the hospital's performance with its observed case mix, and the denominator ("expected") is the number of deaths expected on the basis of the nation's performance with that hospital's case mix. This approach is analogous to a ratio of "observed" to "expected" used in other types of statistical analyses. It conceptually allows for a comparison of a particular hospital's performance given its case-mix to an average hospital's performance with the same case-mix. Thus, a lower ratio indicates lower-than-expected mortality or better quality and a higher ratio indicates higher-than-expected mortality or worse quality.

The predicted hospital outcome (the numerator) is the sum of predicted probabilities of death for all patients at a particular hospital. The predicted probability of each patient in that hospital is calculated using the hospital-specific intercept and patient risk factors. The expected number of deaths (the denominator) is the sum of expected probabilities of death for all patients at a hospital. The expected probability of each patient in a hospital is calculated using a common intercept and patient risk factors.

To assess hospital performance in any reporting period, the model coefficients are re-estimated using the years of data in that period.

Please see attachment for more details on the calculation algorithm.

2a1.21-23 Calculation Algorithm/Measure Logic Diagram URL or attachment:
Attachment
COPD Mortality Calculation Algorithm.pdf

2a1.24 Sampling (Survey) Methodology. If measure is based on a sample (or survey), provide instructions for obtaining the sample, conducting the survey and guidance on minimum sample size (response rate):

N/A –This measure is not based on a sample or survey.

2a1.25 Data Source *(Check all the sources for which the measure is specified and tested*). If other, please describe:
Administrative claims, Other

2a1.26 Data Source/Data Collection Instrument (*Identify the specific data source/data collection instrument, e.g. name of database, clinical registry, collection instrument, etc.*): Administrative Claims
To apply the measure to Medicare FFS patients, Medicare Part A inpatient and outpatient and Part B outpatient claims are used. To apply the measure to a non-Medicare population, inpatient claims data are used.

The Medicare data sources used to create the measure were:
1. Medicare Part A Inpatient and Outpatient and Part B outpatient claims from the Standard Analytic File, including inpatient and outpatient claims for the 12 months prior to an index admission.

2. Medicare Enrollment Database (EDB): This database contains Medicare beneficiary demographic, benefit/coverage, and vital status information. This dataset was used to obtain information on several inclusion/exclusion indicators such as Medicare status on admission as well as vital status. These data have previously been shown to accurately reflect patient vital status (Fleming et al., 1992).

The measure was subsequently tested in 2006 California Patient Discharge Data, a large, linked all-payer database of patient hospital admissions. Records are linked by a unique patient identification number, allowing us to determine patient history from previous hospitalizations. In addition, the unique patient ID number is used to link with state vital statistics records to assess 30-day mortality.

Fleming C, Fisher ES, Chang CH, Bubolz TA, Malenda DJ. Studying outcomes and hospital utilization in the elderly: The advantages of a merged data base for Medicare and Veterans Affairs hospitals. Medical Care 1992; 30(5): 377-391.

2a1.27-29 Data Source/data Collection Instrument Reference Web Page URL or Attachment:

2a1.30-32 Data Dictionary/Code Table Web Page URL or Attachment:
Attachment
COPD ICD 9 to ICD10_Diag + Proc-634620609481436797.pdf

2a1.33 Level of Analysis (*Check the levels of analysis for which the measure is specified and tested)*: Facility

2a1.34-35 Care Setting *(Check all the settings for which the measure is specified and tested)*: Hospital/Acute Care Facility

2a2. Reliability Testing. (*Reliability testing was conducted with appropriate method, scope, and adequate demonstration of reliability*.)

2a2.1 Data/Sample *(Description of the data or sample including number of measured entities; number of patients; dates of data; if a sample, characteristics of the entities included)*:
In measure development and testing, we used Medicare Part A and Part B claims data for calendar years 2007, 2008, and 2009 to test model reliability among Medicare FFS patients. The 2007 cohort included 259,911 admissions from 4,636 hospitals; the 2008 cohort included 299,681 admissions from 4,537 hospitals; and the 2009 cohort included 279,377 admissions from 4,571 hospitals.

2a2.2 Analytic Method *(Describe method of reliability testing & rationale)*:
Data Element Reliability
In constructing the measure in Medicare FFS patients, we aim to utilize only those data elements from the claims that have both face validity and reliability. We avoid the use of fields that are thought to be coded inconsistently across hospitals or providers. Specifically, we use fields that are consequential for payment and which are audited. We identify such variables through empiric

analyses and our understanding of CMS auditing and billing policies and seek to avoid variables which do not meet this standard. For example, “discharge disposition” is a variable in Medicare claims data that is not thought to be a reliable variable for identifying a transfer between two acute care facilities. Thus, we derive a variable using admission and discharge dates as a surrogate for “discharge disposition” to identify hospital admissions involving transfers. This allows us to identify these admissions using variables in the claims data which have greater reliability than the “discharge disposition” variable.
In addition, CMS has in place several hospital auditing programs used to assess overall claims code accuracy, to ensure appropriate billing, and for overpayment recoupment. CMS routinely conducts data analysis to identify potential problem areas and detect fraud, and audits important data fields used in our measures, including diagnosis and procedure codes and other elements that are consequential to payment.
Finally, we assess the reliability of the data elements by comparing model variable frequencies and odds ratios in three years of data.
Measure Result Reliability
The reliability of a measurement is the degree to which repeated measurements of the same entity agree with each other. For measures of hospital performance, the measured entity is naturally the hospital, and reliability is the extent to which repeated measurements of the same hospital give similar results. Accordingly, our approach to assessing reliability is to consider the extent to which assessments of a hospital using different but randomly selected subsets of patients produce similar measures of hospital performance. That is, we take a "test-retest" approach in which hospital performance is measured once using a random subset of patients, then measured again using a second random subset exclusive of the first, and the agreement of the two resulting performance measures compared across hospitals.1
For test-retest reliability of the measure in Medicare FFS patients aged 65 and older, we combined index admissions from successive measurement periods into one dataset, randomly sampled half of patients within each hospital, calculated the measure for each hospital, and repeated the calculation using the second half. Thus, each hospital is measured twice, but each measurement is made using an entirely distinct set of patients. To the extent that the calculated measures of these two subsets agree, we have evidence that the measure is assessing an attribute of the hospital, not of the patients. As a metric of agreement we calculated the intra-class correlation coefficient2, and assessed the values according to conventional standards3. Specifically, we used a combined 2007-2009 sample, randomly split it into two approximately equal subsets of patients, and calculated the RSMR for each hospital for each sample. The agreement of the two RSMRs was quantified for hospitals in each sample using the intra-class correlation as defined by ICC (2,1) by Shrout and Fleiss.2
Using two independent samples provides an honest estimate of the measure’s reliability, compared with using two random but potentially overlapping samples which would exaggerate the agreement. Moreover, because our final measure is derived using hierarchical logistic regression, and a known property of hierarchical logistic regression models is that smaller volume hospitals contribute less ´signal´, a split sample using a single measurement period would introduce extra noise, potentially underestimating the actual test-retest reliability that would be achieved if the measure were reported using three years of data.
References:
1. Rousson V, Gasser T, Seifert B. "Assessing intrarater, interrater and test–retest reliability of continuous measurements," Statistics in Medicine, 2002, 21:3431-3446.
2. Shrout P, Fleiss J. Intraclass correlations: uses in assessing rater reliability. Psychological Bulletin, 1979, 86, 420-3428.
3. Landis J, Koch G, The measurement of observer agreement for categorical data, Biometrics, 1977;33:159-174.

2a2.3 Testing Results *(Reliability statistics, assessment of adequacy in the context of norms for the test conducted)*:
Data Element Reliability
Overall, risk factor frequencies changed very little across the three-year period, and there were no notable differences in the odds ratios across years of data.

Measure Result Reliability
There were 838,969 admissions in the combined three-year sample, with 419,374 in one randomly selected sample and 419,595 in the remaining sample. The agreement between the two RSMRs for each hospital was 0.369, which according to the conventional interpretation is “Fair.”1 The intra-class correlation coefficient is based on a split sample of 3 years of data, resulting in a volume of patients in each sample equivalent to only 1.5 years of data, whereas the measure is likely to be reported with a full three years of data. Based on our experiences with similar measures using split sample, with 4 years (and volume equivalent to 2 years), the intra-class correlation coefficient would be higher and in the moderate range.

References:

1. Landis J, Koch G, The measurement of observer agreement for categorical data, Biometrics, 1977;33:159-174.

2b. VALIDITY. Validity, Testing, including all Threats to Validity: H☐ M☐ L☐ I ☐

2b1.1 Describe how the measure specifications *(measure focus, target population, and exclusions)* are consistent with the evidence cited in support of the measure focus (*criterion 1c)* and identify any differences from the evidence:
N/A

2b2. Validity Testing. (*Validity testing was conducted with appropriate method, scope, and adequate demonstration of validity.)*

2b2.1 Data/Sample *(Description of the data or sample including number of measured entities; number of patients; dates of data; if a sample, characteristics of the entities included)*:
During measure development, we assessed face validity of the final measure via the Technical Expert Panel (TEP). The TEP was comprised of 12 members with diverse perspectives and backgrounds, including clinicians, consumers, hospitals, purchasers, and experts in quality improvement.

TEP members:

Darlene Bainbridge, RN, MS, NHA, CPHQ, CPHRM
President/CEO, Darlene D. Bainbridge & Associates, Inc.

Robert A. Balk, MD
Director of Pulmonary and Critical Care Medicine, Rush University Medical Center

Dale Bratzler, DO, MPH
President and CEO, Oklahoma Foundation for Medical Quality

Scott Cerreta, RRT
Director of Education, COPD Foundation

Gerard J. Criner, MD
Director of Temple Lung Center and Divisions of Pulmonary and Critical Care Medicine, Temple University
Guy D'Andrea, MBA
President, Discern Consulting

Jonathan Fine, MD
Director of Pulmonary Fellowship, Research and Medical Education, Norwalk Hospital

David Hopkins, MS, PhD
Senior Advisor, Pacific Business Group on Health

Fred Martin Jacobs, MD, JD, FACP, FCCP, FCLM
Executive Vice President and Director, Saint Barnabas Quality Institute

Natalie Napolitano, MPH, RRT-NPS
Respiratory Therapist, Inova Fairfax Hospital

Russell Robbins, MD, MBA
Principal and Senior Clinical Consultant, Mercer

2b2.2 Analytic Method *(Describe method of validity testing and rationale; if face validity, describe systematic assessment)*:
Measure validity is demonstrated through prior validity testing done on our other claims-based measures, through use of established measure development guidelines, and by systematic assessment of measure face validity by a TEP of national experts and stakeholder organizations.

Validity of Claims-Based Measures
Our team has demonstrated for a number of prior measures the validity of claims-based measures for profiling hospitals by comparing either the measure results or individual data elements against medical records. CMS validated the six NQF-endorsed measures currently in public reporting (AMI, heart failure, and pneumonia mortality and readmission) with models that used chart-abstracted data for risk adjustment. Specifically, claims model validation was conducted by building comparable models using abstracted medical chart data for risk adjustment for heart failure patients (National Heart Failure data), AMI patients (Cooperative Cardiovascular Project data) and pneumonia patients (National Pneumonia Project dataset). When both models were applied to the same patient population, the hospital risk-standardized rates estimated using the claims-based risk adjustment models had a high level of agreement with the results based on the medical record model, thus supporting the use of the claims-based models for public reporting. Our group has reported these findings in the peer-reviewed literature.1-6

We have also completed two national, multi-site validation efforts for two procedure-based complications measures (for primary elective hip/knee arthroplasty and implantable cardioverter defibrillator). Both projects demonstrated strong agreement between complications coded in claims and abstracted medical chart data.

Validity Indicated by Established Measure Development Guidelines
We developed this measure in consultation with national guidelines for publicly reported outcomes measures, with outside experts, and with the public. The measure is consistent with the technical approach to outcomes measurement set forth in NQF guidance for outcomes measures7 (National Quality Forum, 2010), CMS Measure Management System (MMS) guidance, and the guidance articulated in the American Heart Association scientific statement, “Standards for Statistical Models Used for Public Reporting of Health Outcomes”.8

Validity as Assessed by External Groups
Throughout measure development, we obtained expert and stakeholder input via three mechanisms: regular discussions with an advisory working group, a national Technical Expert Panel (TEP), and a 30-day public comment period in order to increase transparency and to gain broader input into the measure.

The working group was comprised of three physicians who are board-certified in pulmonary and critical care medicine and a pharmacoepidemiologist with expertise in COPD. All members have expertise in quality measure development. The working group meetings addressed key issues surrounding measure development, including detailed discussions regarding the appropriate cohort for inclusion in the measure. The working group provided a forum for focused expert review and discussion of technical issues during measure development prior to consideration by the broader TEP.

In addition to the working group, and in alignment with the CMS Measure Management System, we convened a TEP to provide input and feedback during measure development from a group of recognized experts in relevant fields. To convene the TEP, we released a public call for nominations and selected individuals to represent a range of perspectives including physicians, consumers, and purchasers, as well as individuals with experience in quality improvement, performance measurement, and health care disparities. We held three structured TEP conference calls consisting of presentation of key issues, our proposed approach, and relevant data, followed by open discussion among TEP members. We made a minor modification to the measure cohort based on TEP feedback on the measures.

Following completion of the model, we solicited public comment on the measure through the CMS site link https://www.CMS.gov/MMS/17_CallforPublicComment.asp . The public comments were then posted publicly for 30 days.

Face Validity as Determined by TEP:
To systematically assess face validity, we surveyed the Technical Expert Panel and asked each member to rate the following statement using a six-point scale (1=Strongly Disagree, 2=Moderately Disagree, 3=Somewhat Disagree, 4=Somewhat Agree, 5= Moderately Agree, and 6=Strongly Agree): “The mortality rates obtained from the mortality measure as specified will provide an accurate reflection of quality.”

ICD-10-CM/PCS

The goal of the selection of the ICD-10-CM/PCS coding for the COPD mortality measure was to convert this measure to the new

code set while keeping the measure fully consistent with the intent of the original development with the ICD-9-CM coding.

Elizabeth Drye, MD, SM, and Peter Lindenauer, MD, MSc, assisted with reviewing and confirming the crosswalk for the measure. Jacqueline Grady, MS, created the map for the ICD-9-CM and ICD-10-CM/PCS measure cohort codes using the General Equivalence Mapping crosswalk for the ICD-9-CM and ICD-10-CM/PCS that is located on the Centers for Medicare & Medicaid Services (CMS) website. The ICD-10-CM map for the CC's used for risk adjustment is still under development.

References:

1. Krumholz HM, Wang Y, Mattera JA, Wang Y-F, Han LF, Ingber MJ, Roman S, Normand SL. An administrative claims model suitable for profiling hospital performance based on 30-day mortality rates among patients with an acute myocardial infarction. Circulation. 2006 Apr 4;113(13):1683-92.

2. Krumholz HM, Lin Z, Drye EE, Desai MM, Han LF, Rapp MT, Mattera JA, Normand SL. An administrative claims measure suitable for profiling hospital performance based on 30-day all-cause readmission rates among patients with acute myocardial infarction. Circulation: Cardiovascular Quality and Outcomes. 2011 Mar 1;4(2):243-52.

3. Krumholz HM, Wang Y, Mattera JA, Wang Y-F, Han LF, Ingber MJ, Roman S, Normand SL. An administrative claims model suitable for profiling hospital performance based on 30-day mortality rates among patients with heart failure. Circulation. 2006 Apr 4;113(13):1693-701.

4. Keenan PS, Normand SL, Lin Z, Drye EE, Bhat KR, Ross JS, Schuur JD, Stauffer BD, Bernheim SM, Epstein AJ, Wang Y-F, Herrin J, Chen J, Federer JJ, Mattera JA, Wang Y, Krumholz HM. An administrative claims measure suitable for profiling hospital performance on the basis of 30-day all-cause readmission rates among patients with heart failure. Circulation: Cardiovascular Quality and Outcomes. 2008 Sep;1(1):29-37.

5. Bratzler DW, Normand SL, Wang Y, O´Donnell WJ, Metersky M, Han LF, Rapp MT, Krumholz HM. An administrative claims model for profiling hospital 30-day mortality rates for pneumonia patients. Public Library of Science One. 2011 Apr 12;6(4):e17401.

6. Lindenauer PK, Normand SL, Drye EE, Lin Z, Goodrich K, Desai MM, Bratzler DW, O´Donnell WJ, Metersky ML, Krumholz HM. Development, validation, and results of a measure of 30-day readmission following hospitalization for pneumonia. Journal of Hospital Medicine. 2011 Mar;6(3):142-50.

7. National Quality Forum. National voluntary consensus standards for patient outcomes, first report for phases 1 and 2: A consensus report http://www.nysna.org/images/pdfs/practice/nqf_ana_outcomes_draft10.pdf . Accessed August 19, 2010.

8. Krumholz HM, Brindis RG, Brush JE, et al. Standards for Statistical Models Used for Public Reporting of Health Outcomes: An American Heart Association Scientific Statement From the Quality of Care and Outcomes Research Interdisciplinary Writing Group: Cosponsored by the Council on Epidemiology and Prevention and the Stroke Council Endorsed by the American College of Cardiology Foundation. Circulation. 2006;113(3):456-462.

2b2.3 Testing Results *(Statistical results, assessment of adequacy in the context of norms for the test conducted; if face validity, describe results of systematic assessment)*:

Ten of the 12 TEP members responded to the survey question as follows: Strongly Disagreed (1), Somewhat Agreed (3), Moderately Agreed (4), and Strongly Agreed (2). Of the TEP members who responded, 90% agreed (60% moderately or strongly agreed) that the measure will provide an accurate reflection of quality. We therefore gave the measure a moderate rating for face validity.

These results demonstrate TEP agreement with overall face validity of the measure as specified. Measure validity is also ensured through the processes employed during development, including regular expert and clinical input, and modeling methodologies with demonstrated validity in claims-based measures.

POTENTIAL THREATS TO VALIDITY. (*All potential threats to validity were appropriately tested with adequate results.*)

2b3. Measure Exclusions. (*Exclusions were supported by the clinical evidence in 1c or appropriately tested with results*

demonstrating the need to specify them.)

2b3.1 Data/Sample for analysis of exclusions *(Description of the data or sample including number of measured entities; number of patients; dates of data; if a sample, characteristics of the entities included)*:
In measure development, we used all COPD admissions in 2008 Medicare fee-for-service data (initial cohort which included 436,792 admissions) for the 65 and over model. We used 54,612 COPD admissions in the 2006 all-payer California data for the 18 and over model.

2b3.2 Analytic Method (*Describe type of analysis and rationale for examining exclusions, including exclusion related to patient preference)*:
All exclusions (detailed in section 2a1.8. "Denominator Exclusions") were determined by careful clinical review and have been used based on clinically relevant decisions. These exclusions are consistent with similar NQF-endorsed mortality measures.

2b3.3 Results *(Provide statistical results for analysis of exclusions, e.g., frequency, variability, sensitivity analyses):*
For the 65 and over model, we examined overall frequencies and proportions of the admissions excluded for each exclusion criterion in all COPD admissions in 2008 Medicare fee-for-service data. The initial cohort included 436,792 admissions. The final cohort, after exclusion, included 299,681 admission. Categories are not mutually exclusive.

1) Patients without a complete claims history for the 12 months prior to the date of index admission (n=32,153, 7.36%)
2) Transfer-in patients (n=4,481, 1.03%)
3) Inconsistent or unknown mortality status (n=8, 0.00%)
4) Medicare Hospice enrollment (n=5,913, 1.35%)
5) Patients who leave hospital against medical advice (AMA) (n=2,356, 0.54%)
6) Unreliable Data (n=2, 0.00%)
7) Excluded based on random selection of one hospitalization per patient per year (n=93,389, 23.76%)

For the 18 and over model, we examined overall frequencies and proportions of admissions excluded for each exclusion criterion in all COPD admissions in 2006 California Patient Discharge Data. The initial cohort included 54,612 admissions. The final cohort, after exclusion, included 39,232 admissions. The exclusion categories are not mutually exclusive.

1) Transfers into the hospital (n=2,014, 3.69%)
2) Inconsistent or unknown vital status (n=1, 0.00%)
3) Discharges against medical advice (AMA) (n=1,057, 1.94%)
4) Unreliable data (n=1, 0.00%)
5) Excluded based on random selection of one hospitalization per patient per year (n=12,365, 23.96%)

2b4. Risk Adjustment Strategy. (*For outcome measures, adjustment for differences in case mix (severity) across measured entities was appropriately tested with adequate results.*)

2b4.1 Data/Sample *(Description of the data or sample including number of measured entities; number of patients; dates of data; if a sample, characteristics of the entities included)*:
Measure Development and Validation in Medicare FFS:
For development, we randomly divided the 2008 Medicare cohort derived above into a measure development cohort (N=150,035 admissions from 4,537 hospitals) and a measure validation cohort (N=149,646 admissions from 4,535 hospitals).

Assessment of Temporal Trends in Risk Factors and Model Performance (2007-2009):
We used Medicare cohorts from 2007 through 2009. The 2007 Medicare FFS cohort included 259,911 admissions from 4,636 hospitals; the 2008 cohort included 299,681 admissions from 4,537 hospitals; and the 2009 cohort included 279,377 admissions from 4,571 hospitals.

Limiting Risk-adjustment Data to Inpatient Claims:
To assess the adequacy of risk-adjusting with inpatient data only, we used CMS data for Medicare FFS 65+ patients in California hospitals. California is a diverse state, and, with more than 37 million residents, California represents 12% of the US population. Specifically, we created a 2007 measure cohort with complete one-year history data and 30-day follow-up data (N=13,722).

Applying the Measure to Patients Aged 18 and Older:
To test the model in all-payer data, we used 39,232 cases aged 18 and older in the 2006 California Patient Discharge Data.

2b4.2 Analytic Method (*Describe methods and rationale for development and testing of risk model or risk stratification including selection of factors/variables)*:
Measure Development and Validation in Medicare FFS:
This measure is fully risk-adjusted using a hierarchical logistic regression model to calculate hospital RSMRs accounting for differences in hospital case-mix. (See section 2a1.13. "Statistical risk model and variables" for additional details.)

Approach to Assessing Model Performance:
During measure development using Medicare data for FFS patients 65 and older, we computed five summary statistics for assessing model performance (Harrell and Shih, 2001) for the development and validation cohort:
(1) over-fitting indices (over-fitting refers to the phenomenon in which a model accurately describes the relationship between predictive variables and outcome in the development dataset but fails to provide valid predictions in new patients)
(2) predictive ability
(3) area under the receiver operating characteristic (ROC) curve
(4) distribution of residuals
(5) model chi-square (a test of statistical significance usually employed for categorical data to determine whether there is a good fit between the observed data and expected values; i.e., whether the differences between observed and expected values are attributable to true differences in characteristics or instead the result of chance variation).

Assessment of Temporal Trends in Risk Factors and Model Performance (2007-2009):
We examined the frequency and effect of the parameter estimates for risk-adjustment variables and model performance (C statistic) across years of data.

Limiting Risk-adjustment Data to Inpatient Claims:
To assess the validity of using only admission claims data for risk adjustment, we fit the model separately in the California Medicare FFS 65+ cohort using the full data and using only admission claims data and (a) compared the odds ratios (ORs) for the various risk factors; (b) conducted a reclassification analysis to compare risk prediction at the patient level; (c) compared model performance in terms of the C statistic (discrimination); and (d) compared hospital-level risk-standardized rates (scatter plot, ICC) to assess whether the model with only admission claims data is different from the current model in profiling hospital rates.

Applying the Measure to Patients Aged 18 and Older:
To help determine whether the measure could be applied to a population of patients aged 18+ (i.e., including younger patients aged 18-64), we examined the interaction terms between age (18-64 vs. 65+) and each of the other risk factors in 2006 California Patient Discharge Data. Specifically, we fit the model in all patients 18+ with and without interaction terms and (a) conducted a reclassification analysis to compare risk prediction at the patient level; (b) compared the C statistic; and (c) compared hospital-level risk-standardized rates (scatter plot, ICC) to assess whether the model with interactions is different from the current model in profiling hospital rates.

--
Reference: Harrell FE, Shih YCT. Using full probability models to compute probabilities of actual interest to decision makers. Int J Technol Assess Health Care. 2001;17:17–26.

2b4.3 Testing Results *(Statistical risk model: Provide quantitative assessment of relative contribution of model risk factors; risk model performance metrics including cross-validation discrimination and calibration statistics, calibration curve and risk decile plot, and assessment of adequacy in the context of norms for risk models. Risk stratification: Provide quantitative assessment of relationship of risk factors to the outcome and differences in outcomes among the strata)*:
Measure Development and Validation in Medicare FFS:

Performance Metrics for Development Cohort
The mean RSMR was 8.62%. In the development cohort, the model has strong discrimination and fit. Results are presented below:
Over-fitting indices: (-0.034, 0.985)

Residuals lack of fit: <-2 = 0.00%; [-2, 0) = 91.14%; [0, 2) = 1.66%; [2+ = 6.93%
Model Chi-square [# of covariates]: 6982.11 [42] p < 0.0001
Predictive ability (lowest decile %, highest decile %): 1.52% - 23.74%
Area under the ROC curve = 0.720
Between-hospital variance (standard error) = 0.067 (0.008)

Performance Metrics for Validation Cohort
The mean RSMR was 8.64%. In the validation cohort, the model has strong discrimination and fit. Results are presented below:
Over-fitting indices: (0.009, 1.004)
Residuals lack of fit: <-2 = 0.00%; [-2, 0) = 91.40%; [0, 2) = 1.70%; [2+ = 6.91%
Model Chi-square [# of covariates]: 7051.50 [42] p < 0.0001
Predictive ability (lowest decile %, highest decile %): 1.60% - 23.78%
Area under the ROC curve = 0.723
Between-hospital variance (standard error) = 0.078 (0.009)

Assessment of Temporal Trends in Risk Factors and Model Performance (2007-2009):
Parameter estimates for risk-adjustment variables were consistent across years. In addition, model performance was also consistent across years of data; the C statistic ranged from 0.72 – 0.73.

Limiting Risk-Adjustment Data to Inpatient Claims:
Using 2007 CMS data for Medicare FFS 65+ beneficiaries in California hospitals: (a) the magnitude of odds ratios for most risk factors was similar when comparing the model using full data and using only admission claims data; (b) when comparing the model with full data and with only admission claims data, the reclassification analysis demonstrated good patient-level risk prediction; (c) the C statistic was similar (0.719 vs. 0.722); and (d) hospital-level risk-standardized rates were highly correlated (ICC=0.986).

Applying the Measure to Patients Aged 18 and Older:
When the model was applied to all patients aged 18+ in 2006 California Patient Discharge Data, overall discrimination was good (C statistic=0.744). In addition, there was good discrimination and predictive ability in both those aged 18-64 and those aged 65+. Moreover, the distribution of Pearson residuals was comparable across the patient subgroups. When comparing the model with and without interaction terms, (a) the reclassification analysis demonstrated that nearly all patients were found to be in a similar risk category; (b) the C statistic was nearly identical (0.747 vs. 0.0.744); and (c) hospital-level risk-standardized rates were highly correlated (ICC=0.999). Thus, the inclusion of the interactions did not substantively affect either patient-level model performance or hospital-level results.

Therefore, the measure can be applied to all payer data for patients 18 and older.

2b4.4 If outcome or resource use measure is not risk adjusted, provide rationale and analyses to justify lack of adjustment: The measure is risk-adjusted.

2b5. Identification of Meaningful Differences in Performance. (*The performance measure scores were appropriately analyzed and discriminated meaningful differences in quality.*)

2b5.1 Data/Sample *(Describe the data or sample including number of measured entities; number of patients; dates of data; if a sample, characteristics of the entities included)*:
We used Medicare claims data (2008) and the development sample included 150,035 discharges across 4,537 hospitals. (See denominator and numerator details for sample description.)

2b5.2 Analytic Method *(Describe methods and rationale to identify statistically significant and practically/meaningfully differences in performance)*:
The method for discriminating hospital performance has not been determined. For three publicly reported mortality measures of hospital outcomes developed with similar methodology, CMS currently estimates an interval estimate for each risk-standardized rate to characterize the amount of uncertainty associated with the rate, compares the interval estimate to the national crude rate for the outcome, and categorizes hospitals as “better than,” “worse than,” or “no different than” the US national rate. However, the decision to publicly report this measure and the approach to discriminating performance has not been determined.

See Calculation Algorithm attachment for description of analytic method.

2b5.3 Results *(Provide measure performance results/scores, e.g., distribution by quartile, mean, median, SD, etc.; identification of statistically significant and meaningfully differences in performance)*:
Using the 2008 CMS development cohort noted above, the unadjusted mean hospital mortality rate is 8.59% and ranges from 0.00-100%. The median unadjusted mortality rate is 8.33%. The 5th percentile is 0.00% and the 95th percentile is 16.67%. The interquartile range is 5.40% to 11.11%.

The hospital risk-standardized rates for the development cohort, calculated via the hierarchical logistic regression model, are normally distributed with a mean of 8.62%, and range from 5.9%-13.5%. The median risk-standardized rate is 8.51%. The 5th percentile is 7.22% and the 95th percentile is 10.34%. The interquartile range is 8.01% to 9.12%.
The variation in rates suggests there are meaningful differences in the quality of care received for patients following hospitalization for an acute exacerbation of COPD.

2b6. Comparability of Multiple Data Sources/Methods. (*If specified for more than one data source, the various approaches result in comparable scores.*)

2b6.1 Data/Sample *(Describe the data or sample including number of measured entities; number of patients; dates of data; if a sample, characteristics of the entities included)*:
The measure performs well in both Medicare FFS data and all-payer data.

2b6.2 Analytic Method *(Describe methods and rationale for testing comparability of scores produced by the different data sources specified in the measure)*:
See above.

2b6.3 Testing Results *(Provide statistical results, e.g., correlation statistics, comparison of rankings; assessment of adequacy in the context of norms for the test conducted)*:
See above.

2c. Disparities in Care: H☐ M☐ L☐ I ☐ NA☐ (*If applicable, the measure specifications allow identification of disparities.*)

2c.1 If measure is stratified for disparities, provide stratified results *(Scores by stratified categories/cohorts)*: Measure is not stratified for disparities.

2c.2 If disparities have been reported/identified (e.g., in 1b), but measure is not specified to detect disparities, please explain:
There were no disparities detected during measure development. Please see "Summary of Data on Disparities by Population Group" (Section 1b.4) for additional details.

2.1-2.3 Supplemental Testing Methodology Information:
Attachment
COPD All-payer Data Report_1-13-12_for NQF.pdf

Steering Committee: Overall, was the criterion, *Scientific Acceptability of Measure Properties*, met?
(*Reliability and Validity must be rated moderate or high*) Yes☐ No☐
Provide rationale based on specific subcriteria:

If the Committee votes No, STOP

3. USABILITY

Extent to which intended audiences (e.g., consumers, purchasers, providers, policy makers) can understand the results of the measure and are likely to find them useful for decision making. (evaluation criteria)

C.1 Intended Purpose/ Use *(Check all the purposes and/or uses for which the measure is intended)*: Public Reporting, Quality

Improvement with Benchmarking (external benchmarking to multiple organizations)

3.1 Current Use *(Check all that apply; for any that are checked, provide the specific program information in the following questions)*: Not in use

3a. Usefulness for Public Reporting: H☐ M☐ L☐ I ☐
(*The measure is meaningful, understandable and useful for public reporting.*)

3a.1. Use in Public Reporting - disclosure of performance results to the public at large *(If used in a public reporting program, provide name of program(s), locations, Web page URL(s)).* If not publicly reported in a national or community program, state the reason AND plans to achieve public reporting, potential reporting programs or commitments, and timeline, e.g., within 3 years of endorsement: [*For Maintenance – If not publicly reported, describe progress made toward achieving disclosure of performance results to the public at large and expected date for public reporting; provide rationale why continued endorsement should be considered.*]
This recently-developed measure is designed for use in public reporting but is not yet in use.

3a.2.Provide a rationale for why the measure performance results are meaningful, understandable, and useful for public reporting. If usefulness was demonstrated (e.g., focus group, cognitive testing), describe the data, method, and results: During the measure development process, developers received critical input from an advisory working group comprised of physicians and a pharmacoepidemiologist with expertise in pulmonology, measure methodology, and quality improvement. We also received feedback from a TEP. Meetings were held throughout the development process and we received input and feedback on key methodological and clinical decisions to ensure the measure is meaningful and useful. In addition, similar measures for acute myocardial infarction (AMI) and heart failure underwent consumer testing prior to being publicly report and were found to be useful for publicly reporting outcomes.

3.2 Use for other Accountability Functions (payment, certification, accreditation). If used in a public accountability program, provide name of program(s), locations, Web page URL(s): The measure is not currently used in a public accountability program.

3b. Usefulness for Quality Improvement: H☐ M☐ L☐ I ☐
(*The measure is meaningful, understandable and useful for quality improvement.*)

3b.1. Use in QI. If used in quality improvement program, provide name of program(s), locations, Web page URL(s):
[*For Maintenance – If not used for QI, indicate the reasons and describe progress toward using performance results for improvement*].
Measure is not currently used in a QI program.

3b.2. Provide rationale for why the measure performance results are meaningful, understandable, and useful for quality improvement. If usefulness was demonstrated *(e.g., QI initiative),* describe the data, method and results:
A hospital-level, 30-day mortality measure for COPD patients may create incentives for hospitals to improve quality of care for this high-risk population.

Overall, to what extent was the criterion, *Usability*, met? H☐ M☐ L☐ I ☐
Provide rationale based on specific subcriteria:

4. FEASIBILITY

Extent to which the required data are readily available, retrievable without undue burden, and can be implemented for performance measurement. (evaluation criteria)

4a. Data Generated as a Byproduct of Care Processes: H☐ M☐ L☐ I ☐

4a.1-2 How are the data elements needed to compute measure scores generated? *(Check all that apply).*
Data used in the measure are:
Coded by someone other than person obtaining original information (e.g., DRG, ICD-9 codes on claims)

4b. Electronic Sources: H☐ M☐ L☐ I ☐

4b.1 Are the data elements needed for the measure as specified available electronically *(Elements that are needed to compute measure scores are in defined, computer-readable fields)*: ALL data elements are in a combination of electronic sources

4b.2 If ALL data elements are not from electronic sources, specify a credible, near-term path to electronic capture, OR provide a rationale for using other than electronic sources:

4c. Susceptibility to Inaccuracies, Errors, or Unintended Consequences: H☐ M☐ L☐ I ☐

4c.1 Identify susceptibility to inaccuracies, errors, or unintended consequences of the measurement identified during testing and/or operational use and strategies to prevent, minimize, or detect. If audited, provide results:

Using administrative claims variables for risk adjustment:

This measure uses variables from claims data submitted by hospitals for payment. Prior research has demonstrated that administrative claims data can be used to develop risk-adjusted outcomes measures for both mortality and readmission following hospitalization for acute myocardial infarction,1,2 heart failure,3,4 and pneumonia,5,6 and that the models produce estimates of risk-standardized rates that are very similar to rates estimated by models based on medical record data. This high level of agreement supports the use of the claims-based risk-adjusted models for public reporting. The models have also demonstrated consistent performance across years of claims data.

The approach to gathering risk factors for patients also mitigates the potential limitations of claims data. Because not every diagnosis is coded at every visit, we use inpatient, outpatient, and physician claims data for the year prior to admission, and diagnosis codes during the index admission, for risk adjustment when the measure is used in Medicare FFS data. When the measure is used in all-payer data, only admission claims data (from the index hospitalization and prior year) are used for risk adjustment; however, model testing demonstrated both strong patient-level model performance and consistent hospital-level results when using only admission claims data. The 1-year time frame provides a more comprehensive view of patients' medical histories than is provided by the secondary diagnosis codes from the index hospitalization alone. If a diagnosis appears in some visits and not others, it is included, minimizing the effect of incomplete coding. We were careful, however, to include information about each patient's status at admission and not to adjust for possible complications of the admission. Although some codes, by definition, represent conditions that are present before admission (e.g. cancer), other codes and conditions cannot be differentiated from complications during the hospitalization (e.g. infection or shock). If these are secondary diagnoses coded only in the index admission, then they are not adjusted for in the analysis.

Effect of patient-preferences regarding end-of-life care

COPD is a progressive disease, which in some cases, may result in patients being so disabled and debilitated that they and their families elect not to continue aggressive treatment. In such cases, the best quality care may ultimately be that which supports patients' goals and comfort at the end of life rather than that which prolongs life.

When used in Medicare FFS data, the mortality measure excludes patients who are in Medicare hospice care prior to, or on the day of, their admission to the hospital. Also, the measures account for a number of severe illnesses that may indicate end of life including protein-calorie malnutrition, metastatic cancer, dementia, and age so that hospitals treating older, sicker patients can be compared fairly with hospitals that have a healthier case mix. However, consistent with guidelines for health care quality outcomes measures, the measures do not exclude patients who transitioned to hospice or palliative care during their hospital admission because such transitions may be the result of quality failures that have led to poor clinical outcomes, and, thus, excluding these patients could mask quality problems.

Importantly, patient use of palliative care is not necessarily an indication that a patient is no longer seeking life-sustaining measures. Palliative care is care that is focused on providing patients relief of symptoms. It is increasingly used in patients who are not at the end of life and, therefore, should not be used to exclude patients from a mortality measure.

Finally, it should be noted the intent of a mortality rate is not to convey that all deaths are the result of poor care. The goal is not to have zero deaths. In certain cases, the best quality care may ultimately be that which supports patients´ goals and comfort at the end of life rather than that which prolongs life. The premise is that there are many preventable deaths. The mortality measure is a relative measure of mortality. Knowledge of how an institution performs compared with what might be expected given their case mix is helpful in encouraging efforts to improve outcomes.

References:
1. Krumholz HM, Wang Y, Mattera JA, Wang Y-F, Han LF, Ingber MJ, Roman S, Normand SL. An administrative claims model suitable for profiling hospital performance based on 30-day mortality rates among patients with an acute myocardial infarction. Circulation. 2006 Apr 4;113(13):1683-92.
2. Krumholz HM, Lin Z, Drye EE, Desai MM, Han LF, Rapp MT, Mattera JA, Normand SL. An administrative claims measure suitable for profiling hospital performance based on 30-day all-cause readmission rates among patients with acute myocardial infarction. Circulation: Cardiovascular Quality and Outcomes. 2011 Mar 1;4(2):243-52.
3. Krumholz HM, Wang Y, Mattera JA, Wang Y-F, Han LF, Ingber MJ, Roman S, Normand SL. An administrative claims model suitable for profiling hospital performance based on 30-day mortality rates among patients with heart failure. Circulation. 2006 Apr 4;113(13):1693-701.
4. Keenan PS, Normand SL, Lin Z, Drye EE, Bhat KR, Ross JS, Schuur JD, Stauffer BD, Bernheim SM, Epstein AJ, Wang Y-F, Herrin J, Chen J, Federer JJ, Mattera JA, Wang Y, Krumholz HM. An administrative claims measure suitable for profiling hospital performance on the basis of 30-day all-cause readmission rates among patients with heart failure. Circulation: Cardiovascular Quality and Outcomes. 2008 Sep;1(1):29-37.
5. Bratzler DW, Normand SL, Wang Y, O´Donnell WJ, Metersky M, Han LF, Rapp MT, Krumholz HM. An administrative claims model for profiling hospital 30-day mortality rates for pneumonia patients. Public Library of Science One. 2011 Apr 12;6(4):e17401.
6. Lindenauer PK, Normand SL, Drye EE, Lin Z, Goodrich K, Desai MM, Bratzler DW, O´Donnell WJ, Metersky ML, Krumholz HM. Development, validation, and results of a measure of 30-day readmission following hospitalization for pneumonia. Journal of Hospital Medicine. 2011 Mar;6(3):142-50.

4d. Data Collection Strategy/Implementation: H☐ M☐ L☐ I ☐

A.2 Please check if either of the following apply (*regarding proprietary measures*):
4d.1 Describe what you have learned/modified as a result of testing and/or operational use of the measure regarding data collection, availability of data, missing data, timing and frequency of data collection, sampling, patient confidentiality, time and cost of data collection, other feasibility/implementation issues *(e.g., fees for use of proprietary measures)*:
The measure is not in operational use

Overall, to what extent was the criterion, *Feasibility*, met? H☐ M☐ L☐ I ☐
Provide rationale based on specific subcriteria:

OVERALL SUITABILITY FOR ENDORSEMENT

Does the measure meet all the NQF criteria for endorsement? Yes☐ No☐
Rationale:

If the Committee votes No, STOP.
If the Committee votes Yes, the final recommendation is contingent on comparison to related and competing measures.

5. COMPARISON TO RELATED AND COMPETING MEASURES

If a measure meets the above criteria and there are endorsed or new related measures (either the same measure focus or the same target population) or competing measures (both the same measure focus and the same target population), the measures are compared to address harmonization and/or selection of the best measure before a final recommendation is made.

5.1 If there are related measures *(either same measure focus or target population)* or competing measures *(both the same measure focus and same target population*), list the NQF # and title of all related and/or competing measures:
0229 : Hospital 30-day, all-cause, risk-standardized mortality rate (RSMR) following heart failure (HF) hospitalization for patients 18 and older
0230 : Hospital 30-day, all-cause, risk-standardized mortality rate (RSMR) following acute myocardial infarction (AMI) hospitalization for patients 18 and older
0468 : Hospital 30-day, all-cause, risk-standardized mortality rate (RSMR) following pneumonia hospitalization

5a. Harmonization

5a.1 If this measure has EITHER the same measure focus OR the same target population as NQF-endorsed measure(s): Are the measure specifications completely harmonized? Yes

5a.2 If the measure specifications are not completely harmonized, identify the differences, rationale, and impact on interpretability and data collection burden:

5b. Competing Measure(s)

5b.1 If this measure has both the same measure focus and the same target population as NQF-endorsed measure(s): Describe why this measure is superior to competing measures *(e.g., a more valid or efficient way to measure quality);* OR provide a rationale for the additive value of endorsing an additional measure. *(Provide analyses when possible)*:
N/A

CONTACT INFORMATION

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Co.6 Additional organizations that sponsored/participated in measure development:
MPR: Mathematica Policy Research; RTI: Research Triangle Institute

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ADDITIONAL INFORMATION

Workgroup/Expert Panel involved in measure development
Ad.1 Provide a list of sponsoring organizations and workgroup/panel members' names and organizations. Describe the members' role in measure development.
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Ad.2 If adapted, provide title of original measure, NQF # if endorsed, and measure steward. Briefly describe the reasons for adapting the original measure and any work with the original measure steward:
Measure Developer/Steward Updates and Ongoing Maintenance Ad.3 Year the measure was first released: Ad.4 Month and Year of most recent revision: Ad.5 What is your frequency for review/update of this measure? Ad.6 When is the next scheduled review/update for this measure?
Ad.7 Copyright statement: N/A
Ad.8 Disclaimers:
Ad.9 Additional Information/Comments: Technical Report, calculation algorithm, ICD-9 to ICD-10 maps, and all-payer testing report attached
Date of Submission (*MM/DD/YY*): 01/13/2012

Hospital-level 30-day Mortality Following Admission for an Acute Exacerbation of Chronic Obstructive Pulmonary Disease

Measure Methodology Report

Submitted By Yale New Haven Health Services Corporation/Center for Outcomes Research & Evaluation (YNHHSC/CORE):

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Prepared For:

Centers for Medicare & Medicaid Services (CMS)

Submitted September 29th, 2011

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We would also like to thank the Technical Expert Panel members, who provided important insight and feedback on key measure decisions. These members include:

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1. INTRODUCTION

1.1 Overview of Measure

Chronic obstructive pulmonary disease (COPD) affects as many as 24 million individuals in the United States and is the nation's fourth leading cause of death. Between 1998 and 2008, the number of patients hospitalized annually for acute exacerbations of COPD increased by approximately 18%.[1-3]

Reported in-hospital mortality rates for patients hospitalized for exacerbations of COPD range from 2-5%.[3-7] Information about 30-day mortality rates following hospitalization for COPD is more limited; however, international studies suggest that rates range from 3 to 9%[8,9], and 90-day mortality rates exceed 15%.[10]

To improve the quality of care for COPD patients, the Centers for Medicare & Medicaid Services (CMS) has contracted with Yale New Haven Health Services Corporation/Center for Outcomes Research and Evaluation (YNHHSC/CORE) to develop hospital outcomes measures of the quality of care delivered to patients who are hospitalized with an acute exacerbation of COPD. In this technical report we describe the development of a hospital-level 30-day measure of mortality after hospitalization for an acute exacerbation of COPD. We have also developed a complementary 30-day readmission measure. The methodology and results of the readmission measure are detailed in a separate technical report.

The overall methodological approach for developing this measure is consistent with that used to develop three prior CMS mortality measures endorsed by the National Quality Forum (NQF) for acute myocardial infarction (AMI), heart failure (HF), and pneumonia, which are now publicly reported by CMS on Hospital Compare (www.hospitalcompare.hhs.gov). The YNHHSC/CORE team developed the measure using Medicare claims and enrollment data. To account for the clustering of observations within hospitals and differences in the number of patient admissions across hospitals, we estimated risk-standardized mortality rates (RSMRs) with hierarchical logistic regression models.

1.2 COPD Mortality as a Measure of Quality

Outcomes measures can focus attention on a broad set of healthcare activities that affect patients' well being. Moreover, improving patient outcomes is the ultimate goal of quality improvement, so outcomes are a direct measure of success in quality improvement. Two statutes direct the Department of Health and Human Services to develop outcomes measures. The Deficit Reduction Act (DRA) of 2005 mandated that the Secretary of Health and Human Services publicly report quality measures that include measures of hospital outcomes and efficiency under the Hospital Inpatient Quality Reporting (IQR) Program (formerly the Reporting Hospital Quality Data for Annual Payment Update Program). In addition, the

Affordable Care Act of 2010 promotes the further development and use of outcomes measures.

Measurement of patient outcomes allows for a more comprehensive view of quality of care, encompassing more than that captured by individual process-of-care measures. Complex and critical aspects of care, such as communication between providers, prevention of and response to complications, patient safety, and coordinated transitions to the outpatient environment, all contribute to patient outcomes but are difficult to measure by individual processes.[11,12] Clinical trials and observational studies suggest that several aspects of care provided to patients hospitalized for exacerbations of COPD can have significant effects on mortality, thus supporting the essential construct of mortality as an appropriate outcome to measure quality.[13-16]

The goal of outcomes measurement is to evaluate patient outcomes after accounting for patients' conditions at the time of hospital admission (hospital case-mix). This mortality measure was developed to identify hospitals whose performance is better or worse than would be expected based on their patient case-mix, and therefore promote hospital quality improvement and better inform consumers about care quality.

1.3 Approach to Measure Development

We developed this measure in accordance with national guidelines for publicly reported outcomes measures, and in consultation with clinical and measurement experts, key stakeholders, and the public. The proposed measure is consistent with the technical approach to outcomes measurement set forth in NQF guidance for outcomes measures,[17] CMS' Measure Management System guidance, and the guidance articulated in the American Heart Association scientific statement, "Standards for Statistical Models Used for Public Reporting of Health Outcomes."[18] Throughout measure development, we obtained expert and stakeholder input via two mechanisms: first, through regular discussions with an advisory working group, and second, through meetings with a national Technical Expert Panel (TEP).

The working group was comprised of three physicians who are board-certified in pulmonary and critical care medicine and a pharmacoepidemiologist with expertise in COPD. All members have expertise in quality measure development. The working group meetings addressed key issues surrounding measure development, including detailed discussions regarding the appropriate cohort for inclusion in the measure. The working group provided a forum for focused expert review and discussion of technical issues during measure development prior to consideration by the broader TEP.

In addition to the working group, and in alignment with the CMS' Measure Management System, we convened a TEP, a group of recognized experts and stakeholders in relevant fields, to provide input and feedback during measure

development. To assemble the TEP, we released a public call for nominations and selected individuals with diverse perspectives and backgrounds, including clinicians, consumers, hospitals, purchasers, and experts in quality improvement. We convened three TEP conference calls during the course of measure development. In contrast to the working group meetings, the TEP meetings followed a more structured format consisting of presentation of key issues, relevant data, and our proposed approach. This presentation was followed by open discussion of these issues with TEP members.

Finally, we publicly posted the measure specifications and a summary of the TEP discussions and made a widely distributed call for public comments. We collected these comments through the Measure Management System Web site (https://www.cms.gov/MMS/17_CallforPublicComment.asp). We summarized the public comments for CMS and posted the verbatim comments on a freely accessible Web site. We took the comments we received into consideration during the final stages of measure development.

2. METHODS

2.1 Overview

We developed a hospital-level mortality measure for patients admitted with an acute exacerbation of COPD to non-federal acute care hospitals in the U.S. (including U.S. Virgin Islands, Puerto Rico, Guam, Northern Mariana Islands, and American Samoa).

To develop the measure, we used Medicare administrative datasets that contain hospitalization data for fee-for-service (FFS) Medicare beneficiaries hospitalized in calendar year 2008 with an acute exacerbation of COPD. The datasets also include administrative data on each patient for the 12 months prior to the index admission and the 30 days following it. An index admission is the hospitalization considered for the outcome.

We used hierarchical logistic regression modeling to adjust for differences in patient case-mix and hospital volume, and to account for the clustering of patients within a hospital. We risk-adjusted for patients' comorbid conditions, as identified in both inpatient and outpatient claims for the 12 months prior to the index hospitalization, as well as those present at admission. The model does not risk-adjust for diagnoses that may have been a complication of the index admission.

2.2 Data Sources

Part A inpatient data - contains final action claims data submitted by inpatient hospital providers for Medicare FFS beneficiaries for reimbursement of facility costs. Information in this file includes diagnoses (ICD-9 codes), procedures (ICD-9 procedure codes), Diagnosis Related Groups (DRGs), dates of service, hospital provider, and beneficiary demographic information.

Part A outpatient data - contains final action claims submitted by inpatient hospital providers for Medicare FFS claims paid for the facility component of surgical or diagnostic procedures, emergency room care, and other non-inpatient services performed in a hospital outpatient department or ambulatory surgical/diagnostic center.

Part B data - contains final action claims for the physician services (regardless of setting) and other outpatient care, services, and supplies for Medicare FFS beneficiaries. For purposes of this project, Part B services included only face-to-face encounters between a care provider and patient. We thus do not include services such as laboratory tests, medical supplies, or other ambulatory services.

Medicare Enrollment Database (EDB) - contains Medicare beneficiary demographic, benefit/coverage, and vital status information.

2.3 Outcome Definition

The outcome for this measure is 30-day all-cause mortality. We define this as death from any cause within 30 days of the admission date for the index hospitalization.

2.3.1 30-Day Timeframe

We chose 30-day mortality because it is an important outcome assessed in a standard period that can be strongly influenced by hospital care and the early transition to the outpatient setting. The 30-day standard period is necessary so that the outcome for each patient is measured consistently. Without a standard period, variation in length of stay would have an undue influence on mortality rates, and institutions would have an incentive to adopt strategies to shift deaths out of the hospital without improving quality. This outcome period is consistent with other NQF-endorsed publicly reported mortality measures (AMI, HF, and pneumonia).

2.3.2 All-Cause Mortality

We measure all-cause mortality rather than COPD-specific mortality for several reasons. First, limiting the measure to COPD-related mortalities may limit the focus of efforts to improve care to a narrow set of approaches (such as processes that will prevent a recurrent exacerbation) as opposed to encouraging broader initiatives aimed at improving the overall in-hospital care. Second, cause of death may be unreliably recorded and it is often not possible to exclude quality issues and accountability based on the documented cause of mortality. For example, a COPD patient who develops a hospital-acquired infection may ultimately die from sepsis. It would be inappropriate to treat this death as unrelated to the care the patient received for COPD. Finally, from a patient perspective death due to any cause is the outcome that matters.

2.4 Cohort Definition

COPD is a group of lung diseases characterized by airway obstruction. Patients hospitalized for an acute exacerbation of COPD (AECOPD) present with varying degrees of severity ranging from a worsening of baseline symptoms (dyspnea, cough, and/or sputum) to respiratory failure. To capture the full spectrum of severity of patients hospitalized for an AECOPD, we included patients with a principal diagnosis of COPD, as well as those with a principal diagnosis of respiratory failure who had a secondary diagnosis of an AECOPD. Requiring

AECOPD as a secondary code helps to identify respiratory failure due to COPD exacerbation versus another condition (e.g., heart failure).

Table 1. Final COPD Measure Cohort

ICD-9 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. NOTE: This code is not to be used with any code from categories 491-493.
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 and chronic respiratory failure
799.1*	Other ill-defined and unknown causes of morbidity and mortality; respiratory arrest, cardiorespiratory failure
**Principal diagnosis when combined with a secondary diagnosis of AECOPD (491.21, 491.22, 493.21, or 493.22)*	

2.5 Inclusion/Exclusion Criteria

We used all admissions in 2008 Part A inpatient data to identify the cohort for inclusion in the measure. Admissions eligible for inclusion in the measure are those for patients aged 65 or older admitted to acute care hospitals with AECOPD. The flow chart depicting eligible admissions is presented in Figure 2. An index admission is any eligible admission to an acute care hospital assessed in the

measure for the outcome (died within 30 days of the date of the initial admission). Eligible index admissions are identified using the ICD-9 codes listed in Table 1.

Patients may have more than one admission during an acute episode of care for AECOPD. For example, a patient may be admitted to hospital A and then transferred to hospital B. The initial admission to hospital A and the admission to hospital B are considered one acute episode of care, made up of two inpatient admissions. We identified transferred patients as those who are admitted to an acute care hospital on the same day or following day of discharge from an eligible admission.

We excluded the following admissions from the measure:

- Admissions for patients without continuous enrollment in Medicare FFS for one year prior to the date of the index admission
  Rationale: This ensures full data availability for risk adjustment.

- Admissions for patients transferred into the hospital from another acute care hospital
  Rationale: We assign the outcome for the acute episode of care to the first admitting hospital (see Figure 1 below) because the first hospital initiates patient management and is responsible for any decision to transfer the patient. Therefore, the first admission in an acute episode of care (hospital A) is eligible to be an index admission in the measure. The second or subsequent admissions in the same acute episode are excluded from the measure.

- Admissions for patients with inconsistent or unknown mortality status
  Rationale: We cannot be sure of the accuracy of the outcome; this exclusion affects a very small number of admissions.

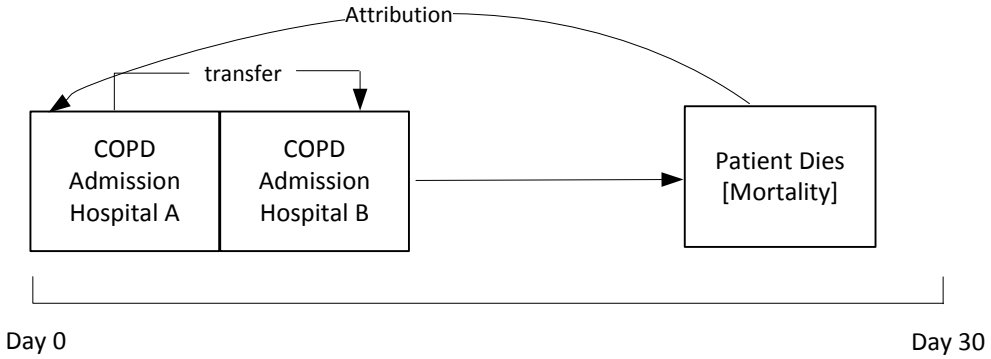
- Admissions for patients enrolled in Medicare Hospice in the 12 months prior to the index hospitalization, up to and including the date of the index admission
  Rationale: It is likely that these patients are continuing to seek comfort measures and their goal may not be survival.

- Admissions for patients who were discharged against medical advice (AMA)
  Rationale: Hospitals and physicians do not have the opportunity to provide the highest quality of care for these patients.

- Admissions with unreliable data (e.g. age > 115)
  Rationale: We cannot be sure of the accuracy of the outcome; this exclusion affects a very small number of admissions.

- After applying the exclusion criteria above, we randomly select one admission per year for patients with multiple index admissions in one year. We therefore exclude the other eligible index admissions in the 12 month period.
  Rationale: Each episode of care must be mutually independent with the same probability of the outcome. The probability of death increases with each subsequent admission and therefore the episodes of care are not mutually independent. We therefore select one admission for inclusion in the measure.

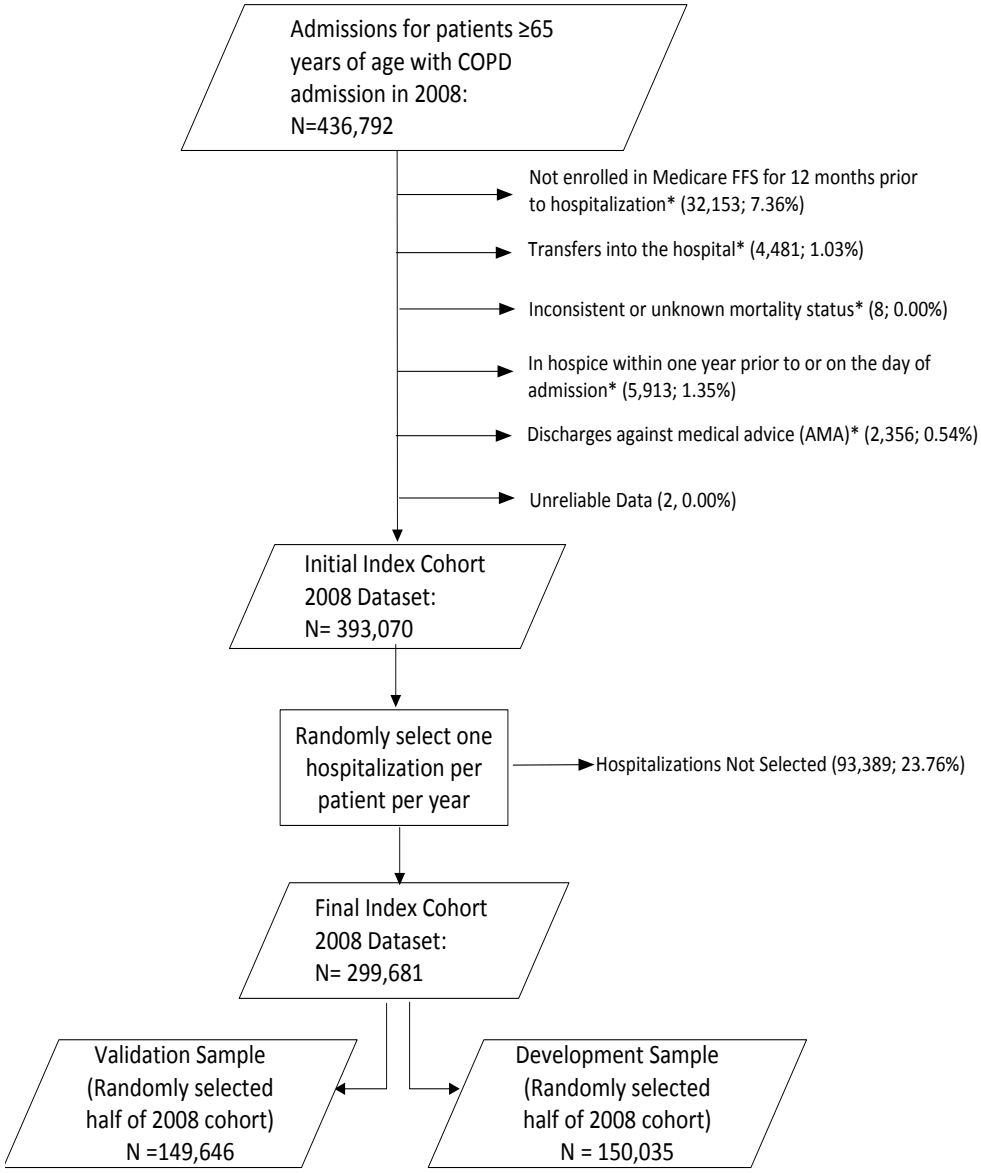
Figure 1. Attribution of Mortality Outcome



2.6 Model Development and Validation Samples

To create the model development and validation samples, we applied the inclusion and exclusion criteria to all 2008 admissions. We randomly selected half of all COPD admissions in 2008 that met the inclusion and exclusion criteria to create a model development sample and used the remaining admissions as our model validation sample.

Figure 2. Model Development and Validation Samples



*Categories are not mutually exclusive

2.7 Approach to Risk Adjustment

The goal of risk adjustment is to account for patient demographic and clinical characteristics in order to illuminate differences in care quality. The model adjusts for case-mix differences based on the clinical status of the patient at the time of admission. Conditions that may represent adverse outcomes due to care received during the index admission are not considered for inclusion in the risk-adjusted model. Although they may increase the risk of mortality, including them as covariates in a risk-adjusted model could attenuate the measure's ability to characterize the quality of care delivered by hospitals. Appendix A lists the conditions not adjusted for if they only appear in the index admission and not in the 12 months prior to admission. This methodology is consistent with NQF guidelines.

The model does not adjust for socioeconomic status (SES), race, ethnicity, or sex. Variation in quality associated with these characteristics may be indicative of disparities in the quality of the care provided to vulnerable populations, and risk adjusting for these factors would obscure these disparities. The model does not adjust for hospital characteristics either (e.g., teaching status) since this would hold different types of hospitals to different quality standards, and because such characteristics may exist on a causal pathway to the outcome, rather than act as confounders. This approach is consistent with NQF guidelines (http://www.qualityforum.org/docs/measure_evaluation_criteria.aspx).

2.8 Candidate and Final Risk-Adjustment Variables

Our goal was to develop a parsimonious model that included clinically relevant variables associated with mortality. The candidate variables for the model were derived from: the index admission, with comorbidities identified from the index admission secondary diagnoses (excluding potential complications), 12-month pre-index inpatient Part A data, outpatient hospital data, and Part B physician data.

For administrative model development, we started with 189 Condition Categories (CCs) which are part of CMS' Hierarchical Condition Categories. The Hierarchical Condition Category (HCC) system groups the ICD-9-CM codes into larger groups that are used in models to predict medical care utilization, spending, mortality or other related measures. CCs are clinically relevant diagnostic groups of the more than 15,000 ICD-9 codes.[19] We used the ICD-9 to CC assignment map, which is maintained by CMS and posted at www.qualitynet.org.

To select candidate variables, a team of clinicians reviewed all 189 CCs and excluded those that were not relevant to the Medicare population (Appendix B) or that were not clinically relevant to the mortality outcome (e.g., attention deficit disorder, female infertility). Clinically relevant CCs were selected as candidate

variables and some of those CCs were then combined into clinically coherent CC groupings. Other candidate variables also included age, history of mechanical ventilation, and sleep apnea, which were selected on the recommendation of clinical experts and identified by ICD-9-CM codes (Table 2).

Table 2. Candidate Model Variables for Risk Adjustment

Category	Variable	CC
Demographics	Age	
Cardiovascular/ Respiratory	History of Mechanical Ventilation	ICD-9 procedure codes: 93.90, 96.70, 96.71, 96.72
	Sleep Apnea	ICD-9 diagnosis codes: 327.20, 327.21, 327.23, 327.27, 327.29, 780.51, 780.53, 780.57
	Respirator Dependence/Respiratory Arrest	CC 77-78
	Cardio-Respiratory Failure and Shock	CC 79
	Congestive Heart Failure	CC 80
	Acute Coronary Syndrome	CC 81-82
	Chronic Atherosclerosis	CC 83-84
	Valvular and Rheumatic Heart Disease	CC 86
	Arrhythmias	CC 92-93
	Other and Unspecified Heart Disease	CC 94
	Vascular or Circulatory Disease	CC 104-106
	Fibrosis of Lung and Other Chronic Lung Disorder	CC 109
	Asthma	CC 110
	Pneumonia	CC 111-113
	Pleural Effusion/Pneumothorax	CC 114
	Other Lung Disorders	CC 115
Comorbidities	History of Infection	CC 1, 3-6
	Septicemia/Shock	CC 2
	Metastatic Cancer and Acute Leukemia	CC 7
	Lung, Upper Digestive Tract, and Other Severe Cancers	CC 8
	Lymphatic, Head and Neck, Brain, and Other Major Cancers; Breast, Colorectal and other Cancers and Tumors; Other Respiratory and Heart Neoplasms	CC 9-11
	Other Digestive and Urinary Neoplasms	CC 12
	Other Neoplasms	CC 13
	Benign Neoplasms of Skin, Breast, Eye	CC 14
	Diabetes and DM Complications	CC 15-20, 119-120
	Protein-Calorie Malnutrition	CC 21
	Disorders of Fluid/Electrolyte/Acid-Base	CC 22-23
	Obesity/Disorders of Thyroid, Cholesterol, Lipids	CC 24
	Liver and Biliary Disease	CC 25-30
	Intestinal Obstruction/Perforation	CC 31
	Pancreatic Disease	CC 32
	Inflammatory Bowel Disease	CC 33
	Peptic Ulcer, Hemorrhage, Other Specified Gastrointestinal Disorders	CC 34
	Other Gastrointestinal Disorders	CC 36
	Bone/Joint/Muscle Infections/Necrosis	CC 37
	Rheumatoid Arthritis and Inflammatory Connective Tissue Disease	CC 38

Category	Variable	CC
	Disorders of the Vertebrae and Spinal Discs	CC 39
	Osteoarthritis of Hip or Knee	CC 40
	Osteoporosis and Other Bone/Cartilage Disorders	CC 41
	Other Musculoskeletal and Connective Tissue Disorders	CC 43
	Severe Hematological Disorders	CC 44
	Disorders of Immunity	CC 45
	Coagulation Defects and Other Specified Hematological Disorders	CC 46
	Iron Deficiency and Other/Unspecified Anemia and Blood Disease	CC 47
	Delirium and Encephalopathy	CC 48
	Dementia or Senility	CC 49-50
	Drug/Alcohol Induced Dependence/Psychosis	CC 51-52
	Drug/Alcohol Abuse, without Dependence	CC 53
	Major Psychiatric Disorders	CC 54-56
	Depression	CC 58
	Anxiety Disorders	CC 59
	Other Psychiatric Disorders	CC 60
	Hemiplegia, Paraplegia, Paralysis, Functional Disability	CC 67-69, 100-102, 177-178
	Polyneuropathy	CC 71
	Parkinson's and Huntington's Diseases	CC 73
	Seizure Disorders and Convulsions	CC 74
	Mononeuropathy, Other Neurological Conditions/Injuries	CC 76
	Heart Infection/Inflammation, Except Rheumatic	CC 85
	Hypertensive Heart and Renal Disease or Encephalopathy	CC 89
	Hypertension	CC 90-91
	Stroke	CC 95-96
	Cerebrovascular Disease	CC 97-99, 103
	Retinal Disorders, except Detachment and Vascular Retinopathies	CC 121
	Glaucoma	CC 122
	Other Eye Disorders	CC 124
	Significant Ear, Nose, and Throat Disorders	CC 125
	Hearing Loss	CC 126
	Other Ear, Nose, Throat, and Mouth Disorders	CC 127
	End-stage Renal Disease or Dialysis	CC 130
	Renal Failure	CC 131
	Urinary Obstruction and Retention	CC 133
	Incontinence	CC 134
	Urinary Tract Infection	CC 135
	Other Urinary Tract Disorders	CC 136
	Pelvic Inflammatory Disease	CC 138
	Other Female Genital Disorders	CC 139
	Male Genital Disorders	CC 140
	Decubitus Ulcer or Chronic Skin Ulcer	CC 148-149
	Cellulitis, Local Skin Infection	CC 152
	Other Dermatological Disorders	CC 153
	Trauma	CC 154-156, 158-161
	Vertebral Fractures	CC 157
	Other Injuries	CC 162
	Poisoning and Allergic Reactions	CC 163

Category	Variable	CC
	Major Complications of Medical Care and Trauma	CC 164
	Other Complications of Medical Care	CC 165
	Major Symptoms, Abnormalities	CC 166
	Minor Symptoms, Signs, Findings	CC 167

To inform final variable selection, a modified approach to stepwise logistic regression was performed. The development sample was used to create 1,000 "bootstrap" samples. For each sample, we ran a logistic stepwise regression that included the candidate variables. The results were summarized to show the percentage of times that each of the candidate variables was significantly associated with mortality ($p<0.001$) in each of the 1,000 repeated samples (e.g., 90 percent would mean that the candidate variable was selected as significant at $p<0.001$ in 90 percent of the estimations). We also assessed the direction and magnitude of the regression coefficients.

The clinical team reviewed these results and decided to retain risk adjustment variables above a 90% cutoff, because they demonstrated a relatively strong and stable association with risk for death and were clinically relevant. Additionally, specific variables with particular clinical relevance to the risk of death were forced into the model (regardless of % selection) to ensure appropriate risk-adjustment for COPD. These included:

Clinical variables associated with COPD:

- history of mechanical ventilation (ICD-9 procedure codes: 93.90, 96.70, 96.71, 96.72)
- history of sleep apnea (ICD-9 diagnosis codes: 327.20, 327.21, 327.23, 327.27, 327.29, 780.51, 780.53, 780.57)

Markers for end of life/frailty:

- decubitus ulcer or chronic skin ulcer (CC 148-149)
- dementia and senility (CC 49 and CC 50, respectively)
- metastatic cancer and acute leukemia (CC 7)
- protein-calorie malnutrition (CC 21)
- hemiplegia/paraplegia/paralysis/functional disability (CC 67-69, 100-102, 177-178)
- stroke (CC 95-96)

Diagnoses with potential asymmetry among hospitals that would impact the validity of the model:

- lung, upper digestive tract, and other severe cancers (CC 8)
- lymphatic, head and neck, brain, and other major cancers; breast, prostate, colorectal and other cancers and tumors; other respiratory and heart neoplasms (CC 9-11)
- other digestive and urinary neoplasms (CC 12)

Final model variables are listed in Table 3.

Table 3. Final Model Variables

Category	Variable	CC
Demographics	Age	
Cardiovascular/ Respiratory	History of Mechanical Ventilation	ICD-9 codes: 93.90, 96.70, 96.71, 96.72
	Sleep Apnea	ICD-9 codes: 327.20, 327.21, 327.23, 327.27, 327.29, 780.51, 780.53, 780.57
	Respirator Dependence/Respiratory Failure	CC 77-78
	Cardio-Respiratory Failure and Shock	CC 79
	Congestive Heart Failure	CC 80
	Chronic Atherosclerosis	CC 83-84
	Arrhythmias	CC 92-93
	Vascular or Circulatory Disease	CC 104-106
	Fibrosis of Lung and Other Chronic Lung Disorder	CC 109
	Asthma	CC 110
	Pneumonia	CC 111-113
	Pleural Effusion/Pneumothorax	CC 114
	Other Lung Disorders	CC 115
Comorbidities	Metastatic Cancer and Acute Leukemia	CC 7
	Lung, Upper Digestive Tract, and Other Severe Cancers	CC 8
	Lymphatic, Head and Neck, Brain, and Other Major Cancers; Breast, Colorectal and other Cancers and Tumors; Other Respiratory and Heart Neoplasms	CC 9-11
	Other Digestive and Urinary Neoplasms	CC 12
	Diabetes and DM Complications	CC 15-20, 119-120
	Protein-Calorie Malnutrition	CC 21
	Disorders of Fluid/Electrolyte/Acid-Base	CC 22-23
	Other Endocrine/Metabolic/Nutritional Disorders	CC 24
	Other Gastrointestinal Disorders	CC 36
	Osteoarthritis of Hip or Knee	CC 40
	Other Musculoskeletal and Connective Tissue Disorders	CC 43
	Iron Deficiency and Other/Unspecified Anemia and Blood Disease	CC 47
	Dementia or Senility	CC 49-50
	Drug/Alcohol Abuse, without Dependence	CC 53
	Other Psychiatric Disorders	CC 60
	Quadriplegia, Paraplegia, Paralysis, Functional Disability	CC 67-69, 100-102, 177-178
	Mononeuropathy, Other Neurological Conditions/Injuries	CC 76
	Hypertension and Hypertensive Disease	CC 90-91
	Stroke	CC 95-96
	Retinal Disorders, except Detachment and Vascular Retinopathies	CC 121
	Other Eye Disorders	CC 124
	Other Ear, Nose, Throat, and Mouth Disorders	CC 127
	Renal Failure	CC 131
	Decubitus Ulcer or Chronic Skin Ulcer	CC 148-149
	Other Dermatological Disorders	CC 153
	Trauma	CC 154-156, 158-161
	Vertebral Fractures	CC 157
	Major Complications of Medical Care and Trauma	CC 164

2.9 Statistical Approach to Model Development

We used a randomly selected split sample of 2008 admissions for model development and candidate variable selection. We used the remaining half of COPD admissions in 2008 to validate the model. We then selected all qualifying COPD admissions in 2007 and 2009 data to assess model reliability across years of data.

Due to the natural clustering of hospitalizations within hospitals, we used hierarchical logistic regression models to model the log-odds of mortality. Death was modeled as a function of patient-level demographic and clinical characteristics and a random hospital-specific intercept. This strategy accounts for within-hospital correlation of the observed outcomes and models the assumption that underlying differences in quality among the healthcare facilities being evaluated lead to systematic differences in outcomes.

We then calculated hospital risk-standardized mortality rates (RSMRs) using a hierarchical logistic regression model. These rates were calculated as the ratio of the predicted number of deaths to the expected number of deaths, multiplied by the national unadjusted mortality rate. The expected number of deaths for each hospital was estimated using that hospital's patient mix and the average intercept. Specifically, for each patient in the data-set, the estimated regression coefficients were multiplied by the observed characteristics and the average of the hospital-specific intercepts was added to this quantity. Then, the quantity was transformed to the probability scale. For each patient within a hospital, these probabilities were summed. The predicted number of deaths in each hospital employed a similar calculation. The predicted number of deaths for each hospital was calculated by summing the predicted mortality rates for all patients in the hospital. The predicted mortality rate for each patient was calculated through the hierarchical model by applying the estimated regression coefficients to the patient characteristics observed and adding the hospital-specific intercept. In order to assess hospital performance in any specific year (e.g., the validation cohort), we estimated the model coefficients using that year's data.

More specifically, we estimated a logistic regression model and a hierarchical generalized linear model which accounts for the clustering of observations within hospitals. The logistic regression model links the outcome to the patient-level risk factors.[20] Let Y_{ij} denote the outcome (equal to 1 if patient dies, zero if patient lives) for the j^{th} patient who had a COPD admission at the i^{th} hospital; $\mathbf{Z}_{ij}$ denotes a set of risk factors based on the data. Let I denote the total number of hospitals and n_i the number of index patient stays in hospital i. We assume the outcome is related linearly to the covariates via a known linked function, h, where

Logistic regression model: $$h(Y_{ij}) = \alpha + \beta \mathbf{Z}_i \quad (1)$$

and $\mathbf{Z}_{ij} = (Z_{1ij}, Z_{2ij}, ..., Z_{pij})$ is a set of *p* patient-specific covariates. In our case, *h* = the logit link.

To account for the natural clustering of observations within hospitals, we then estimate a hierarchical logistic regression model that links the risk factors to the same outcome and a hospital-specific random effect,

Hierarchical logistic regression model: $h(Y_{ij}) = \alpha_i + \beta \mathbf{Z}_{ij}$ (2)

$\alpha_i = \mu + \omega_i; \quad \omega_i \sim N(0, \tau^2)$ (3)

where α_i represents the hospital-specific intercept, $\mathbf{Z}_{ij}$ is defined as above, μ the adjusted average outcome over all hospitals in the sample, and τ^2 the between-hospital variance component.[21] This model separates within-hospital variation from between-hospital variation. Both hierarchical logistic regression models and logistic regression models are estimated using the SAS software system (GLIMMIX and LOGISTIC procedures, respectively).

We first fit the logistic regression model described in Equation (1) using the logit link. Having identified the covariates that were selected, we next fit the hierarchical logistic regression model described in Equations (2) and (3), again using the logit link function; e.g.,

$$\text{Logit } (P(Y_{ij} = 1)) = \alpha_i + \beta \mathbf{Z}_{ij}$$
$$\alpha_i = \mu + \omega_i, \quad \omega_i \sim N(0, \tau^2)$$

where $\mathbf{Z}_{ij}$ consisted of the covariates retained in the logistic regression model. As before, $Y_{ij} = 1$ if patient *j* treated at hospital *i* had the event; 0 otherwise.

2.10 Hospital Performance Reporting

Using the set of risk factors in the logistic regression model, we fit the hierarchical logistic regression model defined by Equations (2) - (3) and estimate the parameters $\hat{\mu}$, $\{\hat{\alpha}_1, \hat{\alpha}_2, ..., \hat{\alpha}_I\}$, $\hat{\beta}$ and $\hat{\tau}^2$. We calculate a standardized outcome, s_i, for each hospital by computing the ratio of the number of predicted deaths to the number of expected deaths, multiplied by the unadjusted overall mortality rate, $\bar{y}$. Specifically, we calculate

Predicted $\hat{y}_{ij}(Z) = h^{-1}(\hat{\alpha}_i + \hat{\beta} \mathbf{Z}_{ij})$ (4)

Expected $\hat{e}_{ij}(Z) = h^{-1}(\hat{\mu} + \hat{\beta} \mathbf{Z}_{ij})$ (5)

$$\hat{s}_i(Z) = \frac{\sum_{j=1}^{n_i} \hat{y}_{ij}(Z)}{\sum_{j=1}^{n_i} \hat{e}_{ij}(Z)} \times \bar{y} \quad (6)$$

If more (fewer) "predicted" cases than "expected" cases have the outcome in a hospital, then s_i will be higher (lower) than the unadjusted average. For each hospital, we compute an interval estimate of s_i to characterize the level of uncertainty around the point estimate using bootstrapping simulations. The point estimate and interval estimate can be used to characterize and compare hospital performance (e.g., higher than expected, as expected, or lower than expected).

2.10.1 Creating Interval Estimates

Because the statistic described in Equation (6) is a complex function of parameter estimates, we use re-sampling and simulation techniques to derive an interval estimate. The bootstrapping simulation has the advantage of avoiding unnecessary distributional assumptions.

2.10.2 Algorithm

Let *I* denote the total number of hospitals in the sample. We repeat steps 1 – 4 below for b = 1,2,…B times:

1. Sample *I* hospitals with replacement.

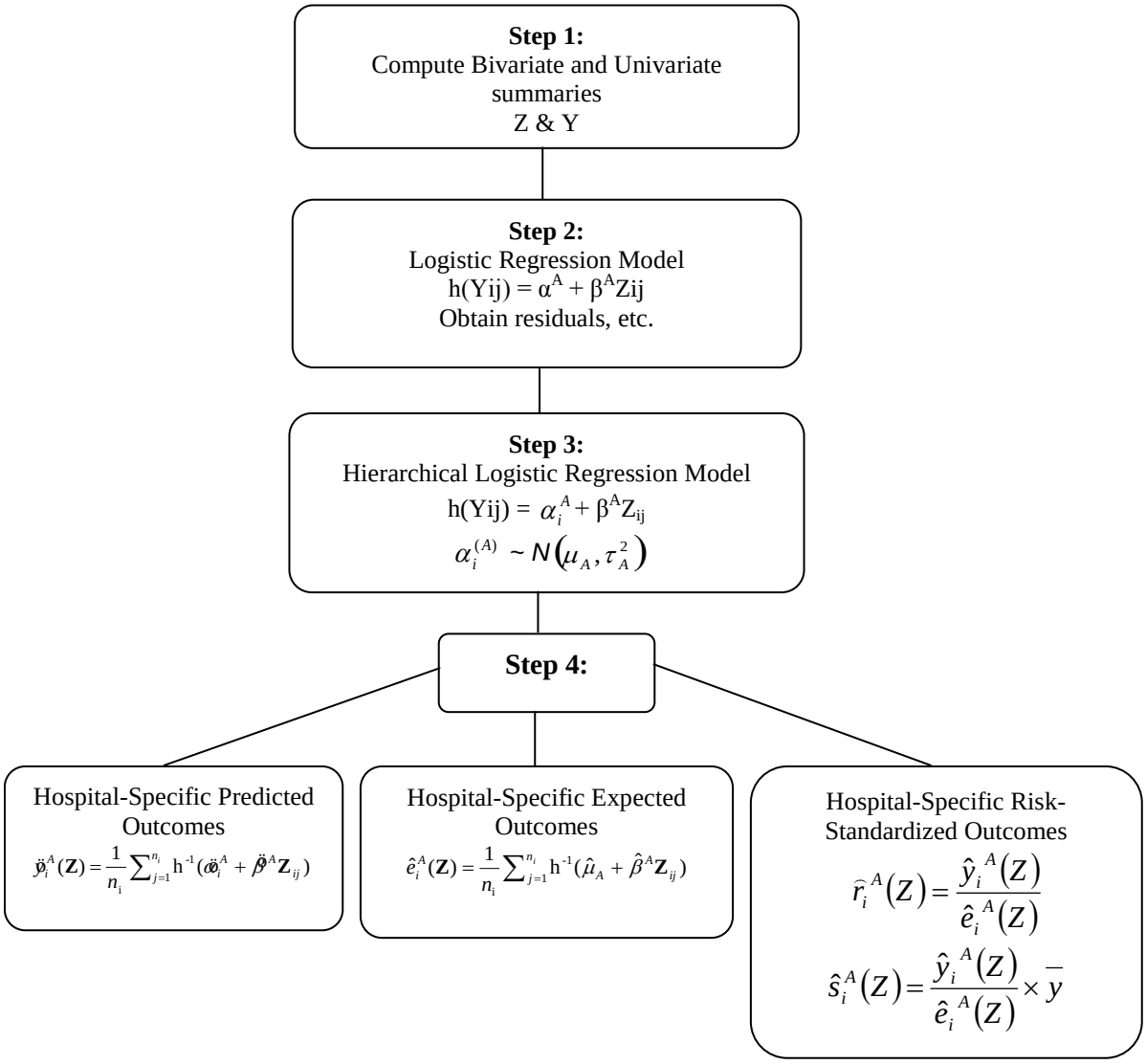
2. Fit the hierarchical logistic regression model using all patients within each sampled hospital. We use as starting values the parameter estimates obtained by fitting the model to all hospitals. If some hospitals are selected more than once in a bootstrapped sample, we treat them as distinct so that we have *I* random effects to estimate the variance components. At the conclusion of Step 2, we have:
   a. $\hat{\beta}^{(b)}$ (the estimated regression coefficients of the risk factors).
   b. The parameters governing the random effects, hospital-adjusted outcomes, distribution, $\hat{\mu}^{(b)}$ and $\hat{\tau}^{2(b)}$.
   c. The set of hospital-specific intercepts and corresponding variances, $\{\hat{\alpha}_i^{(b)}, \hat{\text{var}}(\alpha_i^{(b)}); i = 1,2,...,I\}$.

3. We generate a hospital random effect by sampling from the distribution of the hospital-specific distribution obtained in Step 2c. We approximate the distribution for each random effect by a normal distribution. Thus, we draw $\alpha_i^{(b*)} \sim N\left(\hat{\alpha}_i^{(b)}, \hat{\text{var}}\left(\hat{\alpha}_i^{(b)}\right)\right)$ for the unique set of hospitals sampled in Step 1.

4. Within each unique hospital *i* sampled in Step 1, and for each case *j* in that hospital, we calculate $\hat{y}_{ij}^{(b)}$, $\hat{e}_{ij}^{(b)}$, and $\hat{s}_i(Z)^{(b)}$ where $\hat{\beta}^{(b)}$ and $\hat{\mu}^{(b)}$ are obtained from Step 2 and $\hat{\alpha}_i^{(b*)}$ is obtained from Step 3.

Ninety-five percent interval estimates (or alternative interval estimates) for the hospital-standardized outcome can be computed by identifying the 2.5th and 97.5th percentiles of randomly half of the B estimates (or the percentiles corresponding to the alternative desired intervals).[22] (See Figure 3 below for a diagram of the analysis steps).

Figure 3. Analysis Steps



3. RESULTS

3.1 Model Results

3.1.1 Development and Validation Models

The sample for model development included 150,035 admissions from 4,537 hospitals. The model validation sample included 149,646 admissions from 4,535 hospitals. Results tables are presented at the end of Section 3.

Table 4 conveys the risk factor frequencies, parameter estimates, standard errors, odds ratios (OR), and 95% confidence intervals for the model risk factors in the development and validation samples. Variable frequencies and odds ratios are similar in both samples.

3.1.2 Model Validation

We computed several summary statistics for assessing logistic regression (patient-level) model performance, [23] which included over-fitting indices,[a] predictive ability, area under the receiver operating characteristic (ROC) curve, distribution of residuals, and model chi-square.[b] Table 5 conveys results for the development and validation samples. Model performance is similar in the development and validation samples, with strong model discrimination and fit. Predictive ability is also similar in both samples. The C statistic (area under the receiver operator curve) is 0.72 when the model is applied to either the development or validation sample (Table 5).

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[a] Over-fitting (γ_0, γ_1) provides evidence of over-fitting and requires several steps to calculate. Let *b* denote the *estimated vector* of regression coefficients. *Predicted Probabilities* ($\hat{p}$) = 1/(1+exp{-Xb}), and *Z* = *Xb* (e.g., the linear predictor that is a scalar value for everyone). A new logistic regression model that includes only an intercept and a slope by regressing the logits on Z is fitted in the validation sample; e.g., Logit(P(Y=1|Z)) = $\gamma_0 + \gamma_1 Z$. Estimated values of γ_0 far from 0 and estimated values of γ_1 far from 1 provide evidence of over-fitting.

[b] Chi-Square – A test of statistical significance usually employed for categorical data to determine whether there is a good fit between the observed data and expected values; i.e., whether the differences between observed and expected values are attributable to true differences in characteristics or instead the result of chance variation. The formula for computing the chi-square is as follows:

$$\sum \frac{(O-E)^2}{E}$$

where O = observed value
E = expected value, and
degrees of freedom (df) = (rows-1)(columns-1)

3.1.3 Hierarchical Logistic Regression Model

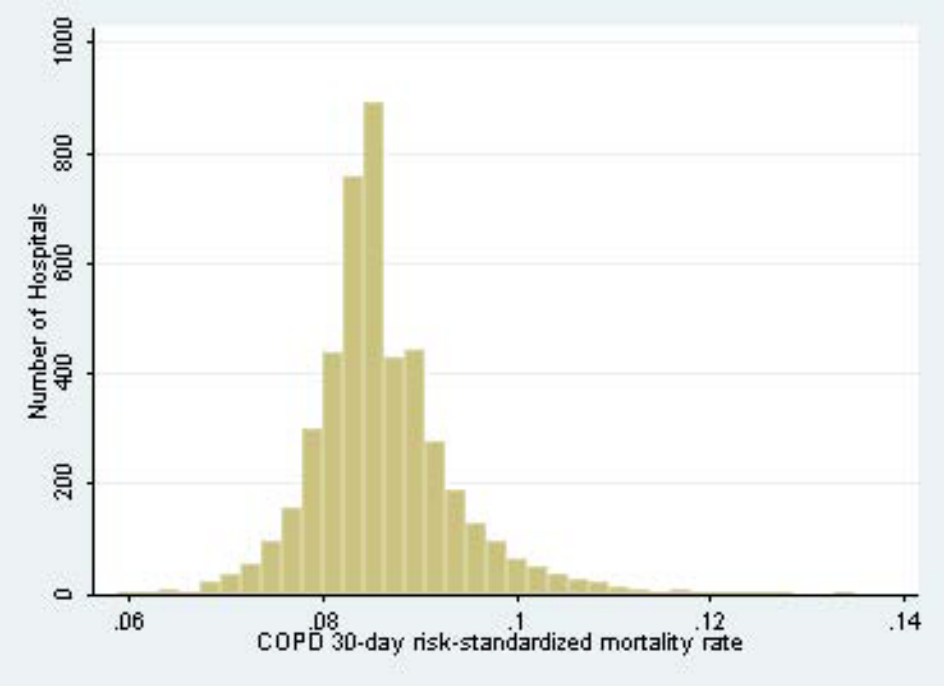
Table 6 conveys the adjusted odds ratios for the development sample calculated via the hierarchical logistic regression model. The odds ratios are nearly identical to those calculated using the logistic regression model (Table 5).

3.1.4 Unadjusted and Adjusted Mortality Rates

The unadjusted mean hospital mortality rate is 8.59% and ranges from 0.00-100%. The median unadjusted mortality rate is 8.33% (data not shown). Figure 4 displays the hospital risk-standardized rates for the development sample, calculated via the hierarchical logistic regression model. The rates are normally distributed with a mean of 8.62%, and range from 5.9%-13.5%. The median risk-standardized rate is 8.51%.

In the hierarchical model, each hospital has its own intercept (random intercept model), which is used to measure the differences in mortality between hospitals while adjusting for case-mix (patient risk factors).

Figure 4. Distribution of Hospital-Level Risk-Standardized Mortality Rates (2008 Development Sample; n=150,035 Admissions from 4,537 Hospitals)



3.2 Model Testing

3.2.1 Reliability of Data Elements

For measure development, we only use data elements in claims that have both face validity and reliability. We do not use fields that are inconsistently coded across providers. We only use fields that are consequential for payment and which are audited. We identify these variables through empiric analyses and our understanding of CMS auditing and billing policies and do not use variables which do not meet this standard. For example, “discharge disposition” is a variable in Medicare claims data that is not consistently coded across hospitals. Thus, we construct an indicator variable as a surrogate for “discharge disposition” to identify patients that are transferred using variables in the claims data with greater reliability, including admit date and discharge date.

In addition, CMS has in place several hospital auditing programs used to assess overall claims code accuracy, ensure appropriate billing, and for overpayment recoupment. CMS routinely conducts data analysis to identify potential problem areas and detect fraud, and audits important data fields used in our measures, including diagnosis and procedure codes, and other elements that are consequential to payment.

The data elements we use are stable over time. We used data from 2007, 2008, and 2009 to assess the data elements over time: 259,911 admissions from 4,636 hospitals in 2007; 299,681 admissions from 4,537 hospitals in 2008; and 279,377 admissions from 4,571 hospitals in 2009. Table 7 conveys the model risk factor frequencies in these samples. Overall, risk factor frequencies changed very little across the three-year period. The percentage of patients with a history of pneumonia (CC 111-113) increased from 45% in 2007 to 50% in 2009. The percentage of patients with a history of diabetes and diabetic complications (CC 15-20, 119-120) increased from 37% in 2007 to 40% in 2009. The percentage of patients diagnosed with other endocrine/metabolic/nutritional disorders (CC 24) increased from 65% in 2007 to 71% in 2009. There were no other notable changes.

Table 8 shows the adjusted odds ratios for the logistic regression (patient-level) model variables and mortality in the 2007, 2008, and 2009 data samples. There are no notable differences in the odds ratios across the samples. The consistency in the rates of the risk adjustment variables and in their relationship to the outcome across the split year sample (development and validation) and the three years of data all demonstrate the reliability of the measure data elements.

3.2.2 Reliability of Model

To test the reliability of the model, we assessed model performance (Table 5) and the effect of the risk adjustment variables on the outcome across the years of data (Table 8). Model performance is similar across years with strong model discrimination and fit. Predictive ability is also similar in both samples. The C statistic (area under the receiver operator curve) is 0.73 for the model in 2007 data and 0.72 for the model in 2009 data (Table 5).

3.2.3 Validity

We have validated six similar NQF-endorsed measures currently used in public reporting (mortality and readmission measures for AMI, heart failure, and pneumonia) against analogous models built with clinical data. We validated the claims-based measures by building comparable models using medical record data for risk adjustment for heart failure patients (National Heart Failure data), AMI patients (Cooperative Cardiovascular Project data) and pneumonia patients (National Pneumonia Project dataset). When the medical record-based models were applied to the corresponding patient population, the hospital risk-standardized rates estimated using the claims-based risk adjustment models had a high level of agreement with the results based on the medical record model, thus supporting the use of the claims-based models for public reporting.

YNHHSC/CORE has also conducted two national, multi-site validation studies for two procedure-based complications measures (primary elective hip/knee arthroplasty and implantable cardioverter defibrillator). Both validation studies demonstrated strong agreement between complications coded in claims and those documented in the medical record. These validation efforts suggest that claims data variables are valid across a variety of conditions and therefore can be used reliably for developing new claims-based outcome measures.

To assess face validity, we surveyed the Technical Expert Panel and asked each member to rate the following statement using a six-point scale (1=Strongly Disagree, 2=Moderately Disagree, 3=Somewhat Disagree, 4=Somewhat Agree, 5=Moderately Agree, and 6=Strongly Agree): “The mortality rates obtained from the mortality measure as specified will provide an accurate reflection of quality.”

Ten of 12 TEP members provided the following responses: Strongly Disagreed (1), Somewhat Agreed (3), Moderately Agreed (4), and Strongly Agreed (2). Hence, of the TEP members who responded, 90%

agreed (60% moderately or strongly agreed) that the measure will provide an accurate reflection of quality.

4. MAIN FINDINGS / SUMMARY

The proposed mortality measure has the potential to significantly improve the quality of care delivered to patients hospitalized with an acute exacerbation of COPD. The cohort for inclusion in the measure is appropriately defined, consisting of patients across the spectrum of COPD. We excluded covariates that are not appropriate for inclusion in a quality measure, including race, gender, socioeconomic status, and physician- and hospital-level variables (e.g., procedural volume). The hierarchical modeling accounts for the clustering of patients within hospitals and differences in sample size across hospitals, thereby allowing for valid comparisons across hospitals. We found variability in the risk-standardized mortality rates across hospitals and these differences remained, even after adjustment for case-mix. Risk-standardized mortality rates can be used for targeted quality improvement efforts by hospitals to decrease rates for death. The risk-standardized model meets recognized standards for outcomes measurement and was developed with extensive input from clinicians and experts in measure development. The model is reliable and valid. In summary, we present a claims-based model of mortality for patients hospitalized for an acute exacerbation of COPD that is suitable for public reporting.

Table 4. Adjusted OR* for Model Risk Factors and Mortality in Development and Validation Samples (Logistic Regression Model)

	Development Sample (n=150,035 admissions at 4,537 hospitals)					Validation Sample (n=149,646 admissions at 4,535 hospitals)				
Variable	**Frequency (%)**	**Estimate**	**SE**	**OR**	**95% CI**	**Frequency (%)**	**Estimate**	**SE**	**OR**	**95% CI**
Demographics										
Age-65 (continuous)	-	0.03	0.001	1.03	(1.03-1.04)	-	0.03	0.001	1.03	(1.03-1.04)
Cardiovascular/Respiratory										
Sleep Apnea (ICD-9 codes: 327.20, 327.21, 327.23, 327.27, 327.29, 780.51, 780.53, 780.57)	9.57	-0.13	0.04	0.87	(0.81-0.94)	9.72	-0.17	0.04	0.84	(0.78-0.91)
History of Mechanical Ventilation (ICD-9 codes: 93.90, 96.70, 96.71, 96.72)	6.00	0.17	0.04	1.19	(1.11-1.28)	6.00	0.15	0.04	1.16	(1.08-1.24)
Respirator Dependence/Respiratory Failure (CC 77-78)	1.15	-0.13	0.08	0.88	(0.76-1.02)	1.20	-0.25	0.08	0.78	(0.67-0.91)
Cardio-Respiratory Failure and Shock (CC 79)	26.35	0.47	0.02	1.60	(1.53-1.68)	26.34	0.47	0.02	1.59	(1.52-1.67)
Congestive Heart Failure (CC 80)	41.50	0.29	0.02	1.33	(1.28-1.40)	41.39	0.27	0.02	1.31	(1.25-1.37)
Chronic Atherosclerosis (CC 83-84)	50.44	-0.14	0.02	0.87	(0.83-0.90)	50.12	-0.10	0.02	0.90	(0.87-0.94)
Arrhythmias (CC 92-93)	37.15	0.16	0.02	1.17	(1.12-1.22)	37.06	0.14	0.02	1.15	(1.10-1.20)
Vascular or Circulatory Disease (CC 104-106)	38.20	0.09	0.02	1.09	(1.05-1.14)	38.09	0.01	0.02	1.02	(0.97-1.06)
Fibrosis of Lung and Other Chronic Lung Disorder (CC 109)	16.96	0.07	0.02	1.08	(1.03-1.13)	17.08	0.11	0.02	1.11	(1.06-1.17)
Asthma (CC 110)	17.05	-0.41	0.03	0.67	(0.63-0.71)	16.90	-0.41	0.03	0.67	(0.63-0.71)
Pneumonia (CC 111-113)	49.46	0.26	0.02	1.29	(1.24-1.35)	49.41	0.24	0.02	1.28	(1.22-1.33)
Pleural Effusion/Pneumothorax (CC 114)	11.78	0.16	0.03	1.17	(1.11-1.23)	11.54	0.17	0.03	1.18	(1.12-1.25)
Other Lung Disorders (CC 115)	53.07	-0.23	0.02	0.80	(0.77-0.83)	53.17	-0.18	0.02	0.83	(0.80-0.87)
Other Comorbid Conditions										
Metastatic Cancer and Acute Leukemia (CC 7)	2.76	0.85	0.05	2.34	(2.13-2.56)	2.79	0.76	0.05	2.15	(1.96-2.35)
Lung, Upper Digestive Tract, and Other Severe Cancers (CC 8)	5.98	0.58	0.04	1.80	(1.67-1.92)	6.02	0.68	0.03	1.98	(1.84-2.11)
Lymphatic, Head and Neck, Brain, and Other Major Cancers; Breast, Prostate, Colorectal and Other Cancers and Tumors; Other Respiratory and Heart Neoplasms (CC 9-11)	14.13	0.02	0.03	1.03	(0.97-1.08)	14.19	0.01	0.03	1.01	(0.96-1.07)
Other Digestive and Urinary Neoplasms(CC 12)	6.91	-0.10	0.04	0.91	(0.84-0.98)	7.05	-0.16	0.04	0.85	(0.79-0.93)

	Development Sample (n=150,035 admissions at 4,537 hospitals)					Validation Sample (n=149,646 admissions at 4,535 hospitals)				
Variable	**Frequency (%)**	**Estimate**	**SE**	**OR**	**95% CI**	**Frequency (%)**	**Estimate**	**SE**	**OR**	**95% CI**
Diabetes and DM Complications (CC 15-20, 119-120)	38.31	-0.10	0.02	0.91	(0.87-0.94)	38.29	-0.10	0.02	0.90	(0.87-0.94)
Protein-calorie Malnutrition (CC 21)	7.40	0.77	0.03	2.17	(2.05-2.29)	7.44	0.73	0.03	2.06	(1.96-2.18)
Disorders of Fluid/Electrolyte/Acid-Base (CC 22-23)	32.05	0.12	0.02	1.13	(1.08-1.18)	32.16	0.21	0.02	1.24	(1.19-1.30)
Other Endocrine/Metabolic/Nutritional Disorders (CC 24)	67.99	-0.29	0.02	0.75	(0.72-0.78)	67.88	-0.27	0.02	0.76	(0.73-0.80)
Other Gastrointestinal Disorders (CC 36)	56.21	-0.21	0.02	0.81	(0.78-0.84)	56.18	-0.25	0.02	0.78	(0.75-0.82)
Osteoarthritis of Hip or Knee (CC 40)	9.32	-0.30	0.04	0.74	(0.69-0.80)	9.33	-0.23	0.04	0.79	(0.74-0.85)
Other Musculoskeletal and Connective Tissue Disorders (CC 43)	64.14	-0.19	0.02	0.83	(0.79-0.86)	64.20	-0.18	0.02	0.83	(0.80-0.87)
Iron Deficiency and Other/Unspecified Anemias and Blood Disease (CC 47)	40.80	0.08	0.02	1.08	(1.04-1.12)	40.72	0.08	0.02	1.09	(1.04-1.13)
Dementia and Senility (CC 49-50)	17.06	0.08	0.02	1.09	(1.04-1.14)	16.97	0.09	0.02	1.09	(1.04-1.15)
Drug/Alcohol Abuse, Without Dependence (CC 53)	23.51	-0.24	0.03	0.79	(0.75-0.83)	23.38	-0.27	0.03	0.76	(0.73-0.80)
Other Psychiatric Disorders (CC 60)	16.49	0.11	0.03	1.12	(1.07-1.18)	16.43	0.11	0.03	1.11	(1.06-1.17)
Quadriplegia, Paraplegia, Functional Disability (CC 67-69, 100-102, 177-178)	4.92	0.03	0.04	1.03	(0.95-1.12)	4.92	0.07	0.04	1.07	(0.99-1.17)
Mononeuropathy, Other Neurological Conditions/Injuries (CC 76)	11.35	-0.16	0.03	0.85	(0.80-0.91)	11.28	-0.13	0.03	0.88	(0.83-0.94)
Hypertension and Hypertensive Disease (CC 90-91)	80.40	-0.25	0.02	0.78	(0.75-0.82)	80.35	-0.24	0.02	0.79	(0.75-0.83)
Stroke (CC 95-96)	6.77	0.002	0.04	1.00	(0.93-1.08)	6.73	-0.03	0.04	0.97	(0.90-1.05)
Retinal Disorders, Except Detachment and Vascular Retinopathies (CC 121)	10.79	-0.14	0.03	0.87	(0.82-0.93)	10.69	-0.10	0.03	0.91	(0.85-0.96)
Other Eye Disorders (CC 124)	19.05	-0.10	0.03	0.90	(0.86-0.95)	19.13	-0.12	0.03	0.89	(0.85-0.94)
Other Ear, Nose, Throat, and Mouth Disorders (CC 127)	35.21	-0.18	0.02	0.83	(0.80-0.87)	35.02	-0.22	0.02	0.80	(0.77-0.84)
Renal Failure (CC 131)	17.92	0.11	0.03	1.12	(1.07-1.18)	18.16	0.12	0.03	1.13	(1.08-1.19)
Decubitus Ulcer or Chronic Skin Ulcer (CC 148-149)	7.42	0.24	0.03	1.27	(1.19-1.35)	7.42	0.29	0.03	1.33	(1.25-1.42)
Other Dermatological Disorders (CC 153)	28.46	-0.10	0.02	0.91	(0.87-0.95)	28.32	-0.11	0.02	0.90	(0.86-0.94)
Trauma (CC 154-156, 158-161)	9.04	0.09	0.03	1.10	(1.03-1.16)	8.99	0.14	0.03	1.15	(1.08-1.22)
Vertebral Fractures (CC 157)	5.01	0.29	0.04	1.33	(1.24-1.44)	4.97	0.26	0.04	1.30	(1.20-1.40)
Major Complications of Medical Care and Trauma (CC 164)	5.47	-0.21	0.04	0.81	(0.75-0.88)	5.55	-0.20	0.04	0.82	(0.76-0.89)

	Development Sample (n=150,035 admissions at 4,537 hospitals)					Validation Sample (n=149,646 admissions at 4,535 hospitals)				
Variable	**Frequency (%)**	**Estimate**	**SE**	**OR**	**95% CI**	**Frequency (%)**	**Estimate**	**SE**	**OR**	**95% CI**

Grey highlighting indicates variable was forced into the model.

SE = Standard Error; OR = Odds Ratio; CI = Confidence Interval

* Each variable in the model is adjusted for the effects of the others

Table 5. Model Performance for Development and Validation Samples (Logistic Regression Model)

Indices	Development Sample	Validation Sample	Data Years	
Year	**2008**	**2008**	**2007**	**2009**
Number of Admissions	150,035	149,646	259,911	279,377
Number of Hospitals	4,537	4,535	4,636	4,571
Mean Risk-Standardized Mortality Rate % (SD)	8.62 (0.94)	8.64 (1.07)	8.97 (1.12)	8.08 (1.09)
Calibration ($\gamma 0$, $\gamma 1$)[3]	(-0.034, 0.985)	(0.009, 1.004)	(0.095, 1.022)	(-0.120, 0.981)
Discrimination -Predictive Ability (lowest decile %, highest decile %)	1.52 - 23.74	1.60 - 23.78	1.54 - 24.64	1.42 - 22.36
Discrimination – Area Under Receiver Operator Curve (C statistic)[4]	0.720	0.723	0.728	0.722
Residuals Lack of Fit (Pearson Residual Fall %)				
<-2	0.00	0.00	0.00	0.00
[-2, 0)	91.14	91.40	91.08	91.93
[0, 2)	1.66	1.70	1.96	1.42
[2+	6.93	6.91	6.96	6.65
Model Wald χ^2 [Number of Covariates] (p-value)	6982.11 [42] (<.0001)	7051.50 [42] (<.0001)	13042.35 [42] (<.0001)	12542.15 [42] (<.0001)
Between-Hospital Variance (τ) (Standard Error)	0.067 (0.008)	0.078 (0.009)	0.067 (0.006)	0.072 (0.006)

[3] Over-Fitting Indices (γ_0, γ_1) provide evidence of over-fitting and require several steps to calculate. Let *b* denote the *estimated vector* of regression coefficients. *Predicted Probabilities* ($\hat{p}$) = 1/(1+exp{-Xb}), and *Z* = *Xb* (e.g., the linear predictor that is a scalar value for everyone). A new logistic regression model that includes only an intercept and a slope by regressing the logits on Z is fitted in the validation sample; e.g., Logit(P(Y=1|Z)) = $\gamma_0 + \gamma_1 Z$. Estimated values of γ_0 far from 0 and estimated values of γ_1 far from 1 provide evidence of over-fitting.

[4] Calculated using logistic regression model

Table 6. Adjusted OR* for Model Risk Factors and Mortality in Development and Validation Sample (Hierarchical Logistic Regression Model)

	Development Sample (150,035 admissions at 4,537 hospitals)					Validation Sample (149,646 admissions at 4,535 hospitals)				
Variable	**Frequency (%)**	**Estimate**	**SE**	**OR**	**95% CI**	**Frequency (%)**	**Estimate**	**SE**	**OR**	**95% CI**
Demographics										
Age-65 (continuous)	-	0.03	0.00	1.03	(1.03-1.04)	-	0.03	0.00	1.03	(1.03-1.04)
Cardiovascular/Respiratory										
Sleep Apnea (ICD-9 codes: 327.20, 327.21, 327.23, 327.27, 327.29, 780.51, 780.53, 780.57)	9.57	-0.14	0.04	0.87	(0.81-0.94)	9.72	-0.17	0.04	0.84	(0.78-0.90)
History of Mechanical Ventilation (ICD-9 codes: 93.90, 96.70, 96.71, 96.72)	6.00	0.17	0.04	1.19	(1.11-1.27)	6.00	0.14	0.04	1.15	(1.08-1.24)
Respirator Dependence/Respiratory Failure (CC 77-78)	1.15	-0.12	0.07	0.89	(0.77-1.02)	1.20	-0.24	0.07	0.78	(0.68-0.91)
Cardio-Respiratory Failure and Shock (CC 79)	26.35	0.47	0.02	1.60	(1.53-1.68)	26.34	0.47	0.02	1.59	(1.52-1.66)
Congestive Heart Failure (CC 80)	41.50	0.29	0.02	1.34	(1.28-1.39)	41.39	0.27	0.02	1.31	(1.25-1.36)
Chronic Atherosclerosis (CC 83-84)	50.44	-0.14	0.02	0.87	(0.83-0.90)	50.12	-0.10	0.02	0.91	(0.87-0.94)
Arrhythmias (CC 92-93)	37.15	0.16	0.02	1.17	(1.12-1.22)	37.06	0.14	0.02	1.15	(1.10-1.20)
Vascular or Circulatory Disease (CC 104-106)	38.20	0.09	0.02	1.09	(1.05-1.14)	38.09	0.02	0.02	1.02	(0.98-1.06)
Fibrosis of Lung and Other Chronic Lung Disorder (CC 109)	16.96	0.07	0.02	1.08	(1.03-1.13)	17.08	0.11	0.02	1.11	(1.06-1.17)
Asthma (CC 110)	17.05	-0.41	0.03	0.67	(0.63-0.70)	16.90	-0.41	0.03	0.67	(0.63-0.70)
Pneumonia (CC 111-113)	49.46	0.26	0.02	1.29	(1.24-1.35)	49.41	0.24	0.02	1.27	(1.22-1.33)
Pleural Effusion/Pneumothorax (CC 114)	11.78	0.16	0.03	1.17	(1.11-1.23)	11.54	0.17	0.03	1.18	(1.12-1.25)
Other Lung Disorders (CC 115)	53.07	-0.23	0.02	0.80	(0.77-0.83)	53.17	-0.18	0.02	0.83	(0.80-0.87)
Other Comorbid Conditions										
Metastatic Cancer and Acute Leukemia (CC 7)	2.76	0.85	0.05	2.34	(2.14-2.56)	2.79	0.77	0.05	2.15	(1.97-2.35)
Lung, Upper Digestive Tract, and Other Severe Cancers (CC 8)	5.98	0.59	0.03	1.80	(1.68-1.92)	6.02	0.68	0.03	1.98	(1.85-2.11)
Lymphatic, Head and Neck, Brain, and Other Major Cancers; Breast, Prostate, Colorectal and Other Cancers and Tumors; Other Respiratory and Heart Neoplasms (CC 9-11)	14.13	0.02	0.03	1.03	(0.97-1.08)	14.19	0.01	0.03	1.01	(0.95-1.06)
Other Digestive and Urinary Neoplasms(CC 12)	6.91	-0.10	0.04	0.91	(0.84-0.98)	7.05	-0.16	0.04	0.85	(0.79-0.92)
Diabetes and DM Complications (CC 15-20, 119-120)	38.31	-0.10	0.02	0.91	(0.87-0.94)	38.29	-0.10	0.02	0.91	(0.87-0.94)
Protein-calorie Malnutrition (CC 21)	7.40	0.78	0.03	2.18	(2.07-2.30)	7.44	0.74	0.03	2.09	(1.98-2.20)
Disorders of Fluid/Electrolyte/Acid-Base (CC 22-23)	32.05	0.12	0.02	1.13	(1.08-1.18)	32.16	0.22	0.02	1.24	(1.19-1.30)
Other Endocrine/Metabolic/Nutritional Disorders (CC 24)	67.99	-0.29	0.02	0.75	(0.72-0.78)	67.88	-0.27	0.02	0.76	(0.73-0.79)
Other Gastrointestinal Disorders (CC 36)	56.21	-0.21	0.02	0.81	(0.78-0.84)	56.18	-0.24	0.02	0.78	(0.75-0.81)
Osteoarthritis of Hip or Knee (CC 40)	9.32	-0.30	0.04	0.74	(0.69-0.79)	9.33	-0.23	0.04	0.80	(0.74-0.85)
Other Musculoskeletal and Connective Tissue Disorders (CC 43)	64.14	-0.19	0.02	0.83	(0.80-0.86)	64.20	-0.18	0.02	0.83	(0.80-0.87)

	Development Sample (150,035 admissions at 4,537 hospitals)					Validation Sample (149,646 admissions at 4,535 hospitals)				
Variable	**Frequency (%)**	**Estimate**	**SE**	**OR**	**95% CI**	**Frequency (%)**	**Estimate**	**SE**	**OR**	**95% CI**
Iron Deficiency and Other/Unspecified Anemias and Blood Disease (CC 47)	40.80	0.08	0.02	1.08	(1.04-1.12)	40.72	0.08	0.02	1.08	(1.04-1.13)
Dementia and Senility (CC 49-50)	17.06	0.08	0.02	1.09	(1.04-1.14)	16.97	0.09	0.02	1.09	(1.04-1.15)
Drug/Alcohol Abuse, Without Dependence (CC 53)	23.51	-0.24	0.02	0.78	(0.75-0.82)	23.38	-0.27	0.02	0.76	(0.72-0.80)
Other Psychiatric Disorders (CC 60)	16.49	0.11	0.02	1.12	(1.07-1.18)	16.43	0.11	0.02	1.12	(1.06-1.17)
Quadriplegia, Paraplegia, Functional Disability (CC 67-69, 100-102, 177-178)	4.92	0.03	0.04	1.03	(0.95-1.12)	4.92	0.07	0.04	1.08	(0.99-1.17)
Mononeuropathy, Other Neurological Conditions/Injuries (CC 76)	11.35	-0.16	0.03	0.85	(0.80-0.91)	11.28	-0.13	0.03	0.88	(0.83-0.93)
Hypertension and Hypertensive Disease (CC 90-91)	80.40	-0.25	0.02	0.78	(0.75-0.82)	80.35	-0.24	0.02	0.79	(0.75-0.83)
Stroke (CC 95-96)	6.77	0.00	0.04	1.00	(0.93-1.08)	6.73	-0.03	0.04	0.98	(0.91-1.05)
Retinal Disorders, Except Detachment and Vascular Retinopathies (CC 121)	10.79	-0.14	0.03	0.87	(0.82-0.93)	10.69	-0.10	0.03	0.90	(0.85-0.96)
Other Eye Disorders (CC 124)	19.05	-0.10	0.02	0.90	(0.86-0.95)	19.13	-0.12	0.02	0.89	(0.85-0.93)
Other Ear, Nose, Throat, and Mouth Disorders (CC 127)	35.21	-0.18	0.02	0.83	(0.80-0.87)	35.02	-0.22	0.02	0.80	(0.77-0.83)
Renal Failure (CC 131)	17.92	0.12	0.02	1.12	(1.07-1.18)	18.16	0.13	0.02	1.13	(1.08-1.19)
Decubitus Ulcer or Chronic Skin Ulcer (CC 148-149)	7.42	0.24	0.03	1.27	(1.19-1.35)	7.42	0.29	0.03	1.33	(1.25-1.42)
Other Dermatological Disorders (CC 153)	28.46	-0.10	0.02	0.90	(0.87-0.94)	28.32	-0.11	0.02	0.89	(0.86-0.93)
Trauma (CC 154-156, 158-161)	9.04	0.09	0.03	1.09	(1.03-1.16)	8.99	0.14	0.03	1.15	(1.08-1.22)
Vertebral Fractures (CC 157)	5.01	0.29	0.04	1.33	(1.24-1.44)	4.97	0.26	0.04	1.29	(1.20-1.39)
Major Complications of Medical Care and Trauma (CC 164)	5.47	-0.21	0.04	0.81	(0.75-0.88)	5.55	-0.20	0.04	0.82	(0.76-0.89)

Grey highlighting indicates variable forced into the model.

* Each variable in the model is adjusted for the effects of the others

Table 7. Risk Factor Frequency (%) in Data Samples

Description	2007 n= 259,911	2008 n= 299,681	2009 n=279,377
Demographics			
Age – 65 (Mean/SD)	-	-	-
Cardiovascular/Respiratory			
Sleep Apnea (ICD-9 codes: 327.20, 327.21, 327.23, 327.27, 327.29, 780.51, 780.53, 780.57)	8.86	9.65	10.87
History of Mechanical Ventilation (ICD-9 codes: 93.90, 96.70, 96.71, 96.72)	6.00	6.00	6.70
Respirator Dependence/Respiratory Failure (CC 77-78)	1.34	1.17	1.17
Cardio-Respiratory Failure and Shock (CC 79)	26.51	26.34	27.76
Congestive Heart Failure (CC 80)	42.79	41.45	42.24
Chronic Atherosclerosis (CC 83-84)	50.20	50.28	50.82
Arrhythmias (CC 92-93)	36.71	37.10	38.11
Vascular or Circulatory Disease (CC 104-106)	37.64	38.15	39.38
Fibrosis of Lung and Other Chronic Lung Disorder (CC 109)	17.87	17.02	17.27
Asthma (CC 110)	18.03	16.98	17.06
Pneumonia (CC 111-113)	45.15	49.44	49.85
Pleural Effusion/Pneumothorax (CC 114)	11.39	11.66	12.49
Other Lung Disorders (CC 115)	51.82	53.12	54.19
Comorbidities			
Metastatic Cancer and Acute Leukemia (CC 7)	2.83	2.78	2.80
Lung, Upper Digestive Tract, and Other Severe Cancers (CC 8)	5.94	6.00	6.22
Lymphatic, Head and Neck, Brain, and Other Major Cancers; Breast, Prostate, Colorectal and Other Cancers and Tumors; Other Respiratory and Heart Neoplasms (CC 9-11)	14.03	14.16	14.22
Other Digestive and Urinary Neoplasms(CC 12)	7.04	6.98	6.81
Diabetes and DM Complications (CC 15-20, 119-120)	37.36	38.30	40.46
Protein-calorie Malnutrition (CC 21)	6.72	7.42	8.21
Disorders of Fluid/Electrolyte/Acid-Base (CC 22-23)	32.51	32.10	33.47
Other Endocrine/Metabolic/Nutritional Disorders (CC 24)	65.10	67.94	70.88
Other Gastrointestinal Disorders (CC 36)	56.37	56.19	56.98
Osteoarthritis of Hip or Knee (CC 40)	9.04	9.32	9.51
Other Musculoskeletal and Connective Tissue Disorders (CC 43)	63.47	64.17	65.28
Iron Deficiency and Other/Unspecified Anemias and Blood Disease (CC 47)	39.41	40.76	42.91
Dementia and Senility (CC 49-50)	16.37	17.01	17.20
Drug/Alcohol Abuse, Without Dependence (CC 53)	23.35	23.45	23.96
Other Psychiatric Disorders (CC 60)	16.63	16.46	17.05
Quadriplegia, paraplegia, functional disability (CC 67-69, 100-102, 177-178)	4.66	4.92	5.23
Mononeuropathy, Other Neurological Conditions/Injuries (CC 76)	11.04	11.31	11.78
Hypertension and Hypertensive Disease (CC 90-91)	79.36	80.37	81.53
Stroke (CC 95-96)	6.87	6.75	6.69
Retinal Disorders, Except Detachment and Vascular Retinopathies (CC 121)	10.36	10.74	11.04
Other Eye Disorders (CC 124)	18.95	19.09	19.19
Other Ear, Nose, Throat, and Mouth Disorders (CC 127)	34.58	35.12	35.52
Renal Failure (CC 131)	16.88	18.04	19.92
Decubitus ulcer or chronic skin ulcer (CC 148-149)	7.04	7.42	7.58
Other Dermatological Disorders (CC 153)	27.80	28.39	28.85
Trauma (CC 154-156, 158-161)	8.54	9.01	9.40
Vertebral Fractures (CC 157)	5.16	4.99	5.04
Major Complications of Medical Care and Trauma (CC 164)	5.45	5.51	5.72

Table 8. Temporal Trend in Adjusted OR* for Model Risk Factors and Mortality in Development and Validation Samples (Logistic Regression Model)

Description	2007 n= 259,911		2008 n= 299,681		2009 n=279,377	
	OR	95% CI	OR	95% CI	OR	95% CI
Demographics						
Age-65 (continuous)	1.03	(1.03-1.04)	1.03	(1.03-1.04)	1.03	(1.03-1.03)
Cardiovascular/Respiratory						
Sleep Apnea (ICD-9 codes: 327.20, 327.21, 327.23, 327.27, 327.29, 780.51, 780.53, 780.57)	0.87	(0.82-0.92)	0.86	(0.82-0.90)	0.84	(0.80-0.89)
History of Mechanical Ventilation (ICD-9 codes: 93.90, 96.70, 96.71, 96.72)	1.20	(1.14-1.27)	1.17	(1.12-1.23)	1.29	(1.22-1.35)
Respirator Dependence/Respiratory Failure (CC 77-78)	0.87	(0.78-0.96)	0.83	(0.74-0.92)	0.81	(0.73-0.91)
Cardio-Respiratory Failure and Shock (CC 79)	1.55	(1.50-1.60)	1.60	(1.55-1.65)	1.53	(1.48-1.58)
Congestive Heart Failure (CC 80)	1.29	(1.25-1.33)	1.32	(1.28-1.36)	1.27	(1.23-1.32)
Chronic Atherosclerosis (CC 83-84)	0.88	(0.85-0.90)	0.89	(0.86-0.91)	0.86	(0.84-0.89)
Arrhythmias (CC 92-93)	1.13	(1.09-1.16)	1.16	(1.13-1.20)	1.14	(1.10-1.17)
Vascular or Circulatory Disease (CC 104-106)	1.05	(1.02-1.08)	1.05	(1.02-1.08)	1.03	(1.00-1.06)
Fibrosis of Lung and Other Chronic Lung Disorder (CC 109)	1.10	(1.06-1.14)	1.09	(1.06-1.13)	1.07	(1.03-1.11)
Asthma (CC 110)	0.68	(0.65-0.70)	0.67	(0.64-0.69)	0.68	(0.65-0.71)
Pneumonia (CC 111-113)	1.47	(1.42-1.52)	1.28	(1.25-1.32)	1.26	(1.22-1.30)
Pleural Effusion/Pneumothorax (CC 114)	1.17	(1.12-1.22)	1.18	(1.13-1.22)	1.18	(1.13-1.22)
Other Lung Disorders (CC 115)	0.79	(0.76-0.81)	0.81	(0.79-0.84)	0.84	(0.82-0.87)
Comorbidities						
Metastatic Cancer and Acute Leukemia (CC 7)	2.29	(2.14-2.45)	2.24	(2.10-2.39)	2.39	(2.24-2.56)
Lung, Upper Digestive Tract, and Other Severe Cancers (CC 8)	1.95	(1.85-2.06)	1.88	(1.79-1.98)	1.85	(1.77-1.94)
Lymphatic, Head and Neck, Brain, and Other Major Cancers; Breast, Prostate, Colorectal and Other Cancers and Tumors; Other Respiratory and Heart Neoplasms (CC 9-11)	1.01	(0.97-1.05)	1.02	(0.98-1.06)	1.02	(0.98-1.06)
Other Digestive and Urinary Neoplasms(CC 12)	0.91	(0.86-0.96)	0.88	(0.83-0.93)	0.81	(0.76-0.86)
Diabetes and DM Complications (CC 15-20, 119-120)	0.90	(0.88-0.93)	0.90	(0.88-0.93)	0.90	(0.87-0.92)
Protein-calorie Malnutrition (CC 21)	2.05	(1.96-2.14)	2.12	(2.04-2.20)	2.09	(2.01-2.18)
Disorders of Fluid/Electrolyte/Acid-Base (CC 22-23)	1.17	(1.13-1.21)	1.18	(1.15-1.22)	1.19	(1.15-1.23)
Other Endocrine/Metabolic/Nutritional Disorders (CC 24)	0.78	(0.75-0.80)	0.76	(0.74-0.78)	0.78	(0.76-0.81)
Other Gastrointestinal Disorders (CC 36)	0.81	(0.79-0.84)	0.80	(0.77-0.82)	0.83	(0.80-0.85)
Osteoarthritis of Hip or Knee (CC 40)	0.72	(0.68-0.76)	0.77	(0.73-0.81)	0.73	(0.69-0.78)
Other Musculoskeletal and Connective Tissue Disorders (CC 43)	0.84	(0.81-0.87)	0.83	(0.81-0.86)	0.82	(0.79-0.84)
Iron Deficiency and Other/Unspecified Anemias and Blood Disease (CC 47)	1.09	(1.05-1.12)	1.08	(1.05-1.11)	1.09	(1.06-1.12)
Dementia and Senility (CC 49-50)	1.09	(1.05-1.13)	1.09	(1.05-1.13)	1.09	(1.06-1.13)
Drug/Alcohol Abuse, Without Dependence (CC 53)	0.76	(0.73-0.79)	0.78	(0.75-0.80)	0.76	(0.73-0.79)
Other Psychiatric Disorders (CC 60)	1.05	(1.01-1.09)	1.12	(1.08-1.16)	1.08	(1.04-1.12)
Quadriplegia, paraplegia, functional disability (CC 67-69, 100-102, 177-178)	1.01	(0.95-1.08)	1.05	(0.99-1.12)	1.04	(0.98-1.10)
Mononeuropathy, Other Neurological Conditions/Injuries (CC 76)	0.82	(0.78-0.86)	0.87	(0.83-0.91)	0.83	(0.80-0.88)
Hypertension and Hypertensive Disease (CC 90-91)	0.81	(0.78-0.83)	0.79	(0.76-0.81)	0.81	(0.78-0.84)
Stroke (CC 95-96)	1.01	(0.96-1.07)	0.99	(0.94-1.04)	1.04	(0.98-1.10)
Retinal Disorders, Except Detachment and Vascular Retinopathies (CC 121)	0.88	(0.84-0.93)	0.89	(0.85-0.93)	0.95	(0.91-0.99)
Other Eye Disorders (CC 124)	0.87	(0.84-0.91)	0.90	(0.87-0.93)	0.93	(0.89-0.96)
Other Ear, Nose, Throat, and Mouth Disorders (CC 127)	0.77	(0.75-0.80)	0.82	(0.79-0.84)	0.81	(0.78-0.83)
Renal Failure (CC 131)	1.15	(1.11-1.20)	1.13	(1.09-1.17)	1.14	(1.10-1.18)
Decubitus ulcer or chronic skin ulcer (CC 148-149)	1.35	(1.29-1.42)	1.30	(1.24-1.36)	1.39	(1.33-1.45)

Description	2007 n= 259,911		2008 n= 299,681		2009 n=279,377	
	OR	95% CI	OR	95% CI	OR	95% CI
Other Dermatological Disorders (CC 153)	0.89	(0.86-0.92)	0.90	(0.87-0.93)	0.91	(0.88-0.94)
Trauma (CC 154-156, 158-161)	1.10	(1.05-1.15)	1.12	(1.07-1.17)	1.14	(1.09-1.19)
Vertebral Fractures (CC 157)	1.37	(1.29-1.45)	1.31	(1.25-1.39)	1.44	(1.36-1.52)
Major Complications of Medical Care and Trauma (CC 164)	0.89	(0.84-0.95)	0.82	(0.77-0.87)	0.89	(0.84-0.94)

* Each variable in the model is adjusted for the effects of the others

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6. APPENDIX

6.1 Appendix A - Conditions That May Represent Adverse Outcomes of Care Received During Index Admission

CC	Description
2	Septicemia/Shock
6	Other Infectious Diseases
17	Diabetes with Acute Complications
23	Disorders of Fluid/Electrolyte/Acid-Base
28	Acute Liver Failure/Disease
31	Intestinal Obstruction/Perforation
34	Peptic Ulcer, Hemorrhage, Other Specified Gastrointestinal Disorders
46	Coagulation Defects and Other Specified Hematological Disorders
48	Delirium and Encephalopathy
75	Coma, Brain Compression/Anoxic Damage
77	Respirator Dependence/Tracheostomy Status
78	Respiratory Arrest
79	Cardio-respiratory failure and shock
80	Congestive heart failure
81	Acute myocardial infarction
82	Unstable angina
92	Specified Heart Arrhythmias
93	Other Heart Rhythm and Conduction Disorders
95	Cerebral Hemorrhage
96	Ischemic or Unspecified Stroke
97	Precerebral Arterial Occlusion and Transient Cerebral Ischemia
100	Hemiplegia/Hemiparesis
101	Cerebral Palsy and Other Paralytic Syndromes
102	Speech, Language, Cognitive, Perceptual
104	Vascular Disease with Complications
105	Vascular Disease
106	Other Circulatory Disease
111	Aspiration and Specified Bacterial Pneumonias
112	Pneumococcal Pneumonia, Emphysema, Lung Abscess
114	Pleural Effusion/Pneumothorax
130	Dialysis Status
131	Renal failure
132	Nephritis
133	Urinary Obstruction and Retention
135	Urinary Tract Infection
148	Decubitus Ulcer of Skin
152	Cellulitis, Local Skin Infection
154	Severe Head Injury
155	Major Head Injury
156	Concussion or Unspecified Head Injury
158	Hip Fracture/Dislocation
159	Major Fracture, Except of Skull, Vertebrae, or Hip
163	Poisonings and Allergic Reactions
164	Major Complications of Medical Care and Trauma
165	Other Complications of Medical Care
174	Major Organ Transplant Status
175	Other Organ Transplant/Replacement
177	Amputation Status, Lower Limb/Amputation
178	Amputation Status, Upper Limb

6.2 Appendix B - CCs Not Considered for Risk Adjustment

CC	Description	Rationale
66	Attention Deficit Disorder	Pediatric ; Low frequency
123	Cataracts	Marker of clinical practice, not clinically relevant
129	End Stage Renal Disease	Not included in CMS-HCC Model
137	Female Infertility	Irrelevant to Medicare FFS Population
141	Ectopic Pregnancy	Irrelevant to Medicare FFS Population
142	Miscarriage/Abortion	Irrelevant to Medicare FFS Population
143	Completed Pregnancy with Major Complications	Irrelevant to Medicare FFS Population
144	Completed Pregnancy with Complications	Irrelevant to Medicare FFS Population
145	Completed Pregnancy without Complication	Irrelevant to Medicare FFS Population
146	Uncompleted Pregnancy with Complications	Irrelevant to Medicare FFS Population
147	Uncompleted Pregnancy with No or Minor Complications	Irrelevant to Medicare FFS Population
168	Extremely Low Birthweight Neonates	Fetal Effects; Irrelevant to Medicare FFS Population
169	Very Low Birthweight Neonates	Fetal Effects; Irrelevant to Medicare FFS Population
170	Serious Perinatal Problems Affecting Newborn	Fetal Effects; Irrelevant to Medicare FFS Population
171	Other Perinatal Problems Affecting Newborn	Fetal Effects; Irrelevant to Medicare FFS Population
172	Normal, Single Birth	Fetal Effects; Irrelevant to Medicare FFS Population
173	Major Organ Transplant	Not included in CMS-HCC Model
176	Artificial Openings for Feeding or Elimination	CC too heterogeneous; Mix of disparate codes
179	Post-Surgical States/Aftercare/Elective	CC too heterogeneous; Mix of disparate codes
180	Radiation Therapy	CC too heterogeneous; Mix of disparate codes
181	Chemotherapy	CC too heterogeneous; Mix of disparate codes
182	Rehabilitation	CC too heterogeneous; Mix of disparate codes
183	Screening/Observation/Special Exams	CC too heterogeneous; Mix of disparate codes
184	History of Disease	CC too heterogeneous; Mix of disparate codes
185	Oxygen	Not included in CMS-HCC Model; Durable Medical Equipment (DME)
186	CPAP/IPPB/Nebulizers	Not included in CMS-HCC Model; DME
187	Patient Lifts, Power Operated Vehicles, Beds	Not included in CMS-HCC Model; DME
188	Wheelchairs, Commodes	Not included in CMS-HCC Model; DME
189	Walkers	Not included in CMS-HCC Model; DME

COPD Mortality Calculation Algorithm

We estimated a logistic regression model and a hierarchical generalized linear model which accounts for the clustering of observations within hospitals. The logistic regression model links the outcome to the patient-level risk factors.[20] Let Y_{ij} denote the outcome (equal to 1 if patient dies, zero if patient lives) for the j^{th} patient who had a COPD admission at the i^{th} hospital; $\mathbf{Z}_{ij}$ denotes a set of risk factors based on the data. Let I denote the total number of hospitals and n_i the number of index patient stays in hospital i. We assume the outcome is related linearly to the covariates via a known linked function, h, where

Logistic regression model: $$h(Y_{ij}) = \alpha + \beta \mathbf{Z}_{ij} \quad (1)$$

and $\mathbf{Z}_{ij} = (Z_{1ij}, Z_{2ij}, \ldots, Z_{pij})$ is a set of p patient-specific covariates. In our case, h = the logit link.

To account for the natural clustering of observations within hospitals, we then estimate a hierarchical logistic regression model that links the risk factors to the same outcome and a hospital-specific random effect,

Hierarchical logistic regression model: $$h(Y_{ij}) = \alpha_i + \beta \mathbf{Z}_{ij} \quad (2)$$
$$\alpha_i = \mu + \omega_i; \qquad \omega_i \sim N(0, \tau^2) \quad (3)$$

where α_i represents the hospital-specific intercept, $\mathbf{Z}_{ij}$ is defined as above, μ the adjusted average outcome over all hospitals in the sample, and τ^2 the between-hospital variance component.[21] This model separates within-hospital variation from between-hospital variation. Both hierarchical logistic regression models and logistic regression models are estimated using the SAS software system (GLIMMIX and LOGISTIC procedures, respectively).

We first fit the logistic regression model described in Equation (1) using the logit link. Having identified the covariates that were selected, we next fit the hierarchical logistic regression model described in Equations (2) and (3), again using the logit link function; e.g.,

$$\text{Logit } (P(Y_{ij} = 1)) = \alpha_i + \beta \mathbf{Z}_{ij}$$
$$\alpha_i = \mu + \omega_{i,} \quad \omega_i \sim N(0, \tau^2)$$

where $\mathbf{Z}_{ij}$ consisted of the covariates retained in the logistic regression model. As before, $Y_{ij} = 1$ if patient j treated at hospital i had the event; 0 otherwise.

Hospital Performance Reporting

Using the set of risk factors in the logistic regression model, we fit the hierarchical logistic regression model defined by Equations (2) - (3) and estimate the parameters $\hat{\mu}$, $\{\hat{\alpha}_1, \hat{\alpha}_2, ..., \hat{\alpha}_I\}$, $\hat{\beta}$ and $\hat{\tau}^2$. We calculate a standardized outcome, s_i, for each hospital by computing the ratio of the number of predicted deaths to the number of expected deaths, multiplied by the unadjusted overall mortality rate, $\bar{y}$. Specifically, we calculate

Predicted $\hat{y}_{ij}(Z) = h^{-1}(\hat{\alpha}_i + \hat{\beta}\mathbf{Z}_{ij})$ (4)

Expected $\hat{e}_{ij}(Z) = h^{-1}(\hat{\mu} + \hat{\beta}\mathbf{Z}_{ij})$ (5)

$$\hat{s}_i(Z) = \frac{\sum_{j=1}^{n_i} \hat{y}_{ij}(Z)}{\sum_{j=1}^{n_i} \hat{e}_{ij}(Z)} \times \bar{y} \quad (6)$$

If more (fewer) "predicted" cases than "expected" cases have the outcome in a hospital, then s_i will be higher (lower) than the unadjusted average. For each hospital, we compute an interval estimate of s_i to characterize the level of uncertainty around the point estimate using bootstrapping simulations. The point estimate and interval estimate can be used to characterize and compare hospital performance (e.g., higher than expected, as expected, or lower than expected).

Creating Interval Estimates

Because the statistic described in Equation (6) is a complex function of parameter estimates, we use re-sampling and simulation techniques to derive an interval estimate. The bootstrapping simulation has the advantage of avoiding unnecessary distributional assumptions.

Calculation Algorithm

Let *I* denote the total number of hospitals in the sample. We repeat steps 1 – 4 below for b = 1,2,…B times:

1. Sample *I* hospitals with replacement.

2. Fit the hierarchical logistic regression model using all patients within each sampled hospital. We use as starting values the parameter estimates obtained by fitting the model to all hospitals. If some hospitals are selected more than once in a bootstrapped sample, we

treat them as distinct so that we have *I* random effects to estimate the variance components. At the conclusion of Step 2, we have:

a. $\hat{\beta}^{(b)}$ (the estimated regression coefficients of the risk factors).
b. The parameters governing the random effects, hospital-adjusted outcomes, distribution, $\hat{\mu}^{(b)}$ and $\hat{\tau}^{2(b)}$.
c. The set of hospital-specific intercepts and corresponding variances, $\{\hat{\alpha}_i^{(b)}, \hat{\text{var}}\left(\alpha_i^{(b)}\right); i = 1,2,...,I\}$.

3. We generate a hospital random effect by sampling from the distribution of the hospital-specific distribution obtained in Step 2c. We approximate the distribution for each random effect by a normal distribution. Thus, we draw $\alpha_i^{(b^*)} \sim N\left(\hat{\alpha}_i^{(b)}, \hat{\text{var}}\left(\hat{\alpha}_i^{(b)}\right)\right)$ for the unique set of hospitals sampled in Step 1.

4. Within each unique hospital *i* sampled in Step 1, and for each case *j* in that hospital, we calculate $\hat{y}_{ij}^{(b)}$, $\hat{e}_{ij}^{(b)}$, and $\hat{s}_i(Z)^{(b)}$ where $\hat{\beta}^{(b)}$ and $\hat{\mu}^{(b)}$ are obtained from Step 2 and $\hat{\alpha}_i^{(b^*)}$ is obtained from Step 3.

Ninety-five percent interval estimates (or alternative interval estimates) for the hospital-standardized outcome can be computed by identifying the 2.5th and 97.5th percentiles of randomly half of the B estimates (or the percentiles corresponding to the alternative desired intervals).[22] (See Figure 3 below for a diagram of the analysis steps).

Figure 1. Analysis Steps

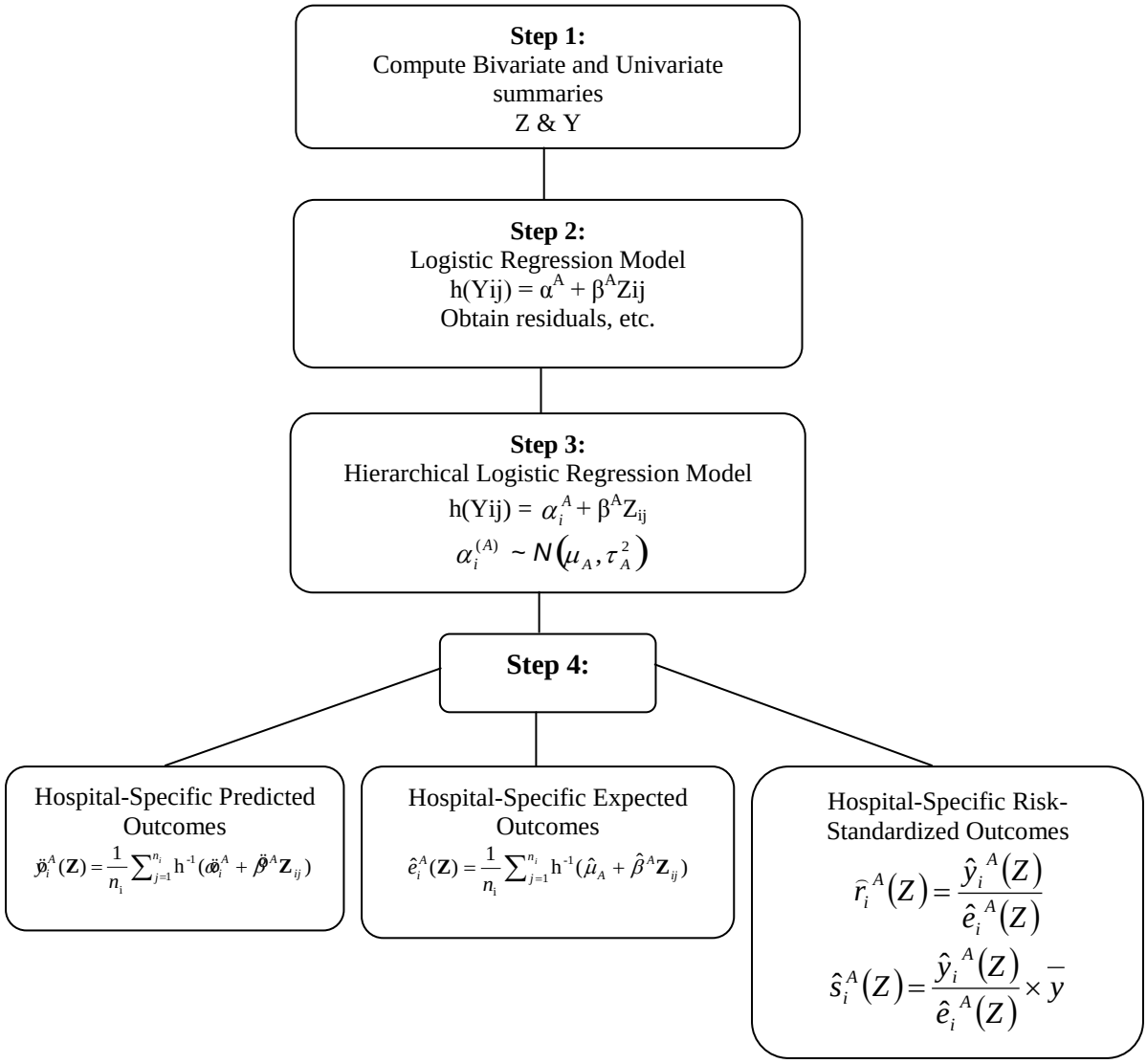

Table 1. COPD Cohort ICD-9 Codes Mapped to ICD-10 Codes

COPD ICD-9 Diagnosis Code	ICD-9 Diagnosis Code Description	ICD- 10 Diagnosis Code	ICD-10 Diagnosis Code Description	Flag
49121	Obstructive chronic bronchitis with (acute) exacerbation	J441	Chronic obstructive pulmonary disease with (acute) exacerbation	10000
4918	Other chronic bronchitis	J418	Mixed simple and mucopurulent chronic bronchitis	10000
4919	Unspecified chronic bronchitis	J42	Unspecified chronic bronchitis	00000
4928	Other emphysema	J439	Emphysema, unspecified	10000
49320	Chronic obstructive asthma, unspecified	J449	Chronic obstructive pulmonary disease, unspecified	10000
496	Chronic airway obstruction, not elsewhere classified			10000
49321	Chronic obstructive asthma with status asthmaticus	J440	Chronic obstructive pulmonary disease with acute lower respiratory infection	10000
49322	Chronic obstructive asthma with (acute) exacerbation	J441	Chronic obstructive pulmonary disease with (acute) exacerbation	10000
51881	Acute respiratory failure	J9600	Acute respiratory failure, unspecified whether with hypoxia or hypercapnia	10000
		J9690	Respiratory failure, unspecified, unspecified whether with hypoxia or hypercapnia	10000
51882	Other pulmonary insufficiency, not elsewhere classified	J80	Acute respiratory distress syndrome	10000
51884	Acute and chronic respiratory failure	J9620	Acute and chronic respiratory failure, unspecified whether with hypoxia or hypercapnia	10000
7991	Respiratory arrest	R092	Respiratory arrest	00000

Table 2. COPD Measures Risk Factors ICD-9 Diagnosis Codes Mapped to ICD-10 Codes

Risk Factor ICD-9 Diagnosis Code	ICD-9 Diagnosis Code Description	ICD-10 Diagnosis Code	ICD-10 Diagnosis Code Description	Flag
32720	Organic sleep apnea, unspecified	G4730	Sleep apnea, unspecified	10000
32721	Primary central sleep apnea	G4731	Primary central sleep apnea	00000
32723	Obstructive sleep apnea (adult)(pediatric)	G4733	Obstructive sleep apnea (adult) (pediatric)	00000
32727	Central sleep apnea in conditions classified elsewhere	G4737	Central sleep apnea in conditions classified elsewhere	00000
32729	Other organic sleep apnea	G4739	Other sleep apnea	10000
78051	Insomnia with sleep apnea, unspecified			10000
78053	Hypersomnia with sleep apnea, unspecified	G4730	Sleep apnea, unspecified	10000
78057	Unspecified sleep apnea			10000

Table 3. COPD Measures Risk Factors ICD-9 Procedure Codes Mapped to ICD-10 Codes

Risk Factor ICD-9 Procedure Code	ICD-9 Procedure Code Description	ICD-10 Procedure Code	ICD-10 Procedure Description	Flag
9390	Non-invasive mechanical ventilation	5A09357	Assistance with Respiratory Ventilation, Less than 24 Consecutive Hours, Continuous Positive Ai	10000
		5A09457	Assistance with Respiratory Ventilation, 24-96 Consecutive Hours, Continuous Positive Airway Pr	10000
		5A09557	Assistance with Respiratory Ventilation, Greater than 96 Consecutive Hours, Continuous Positive	10000
9670	Continuous invasive mechanical ventilation of unspecified duration	5A1935Z	Respiratory Ventilation, Less than 24 Consecutive Hours	10000
		5A1945Z	Respiratory Ventilation, 24-96 Consecutive Hours	10000
		5A1955Z	Respiratory Ventilation, Greater than 96 Consecutive Hours	10000
9671	Continuous invasive mechanical ventilation for less than 96 consecutive hours	5A1935Z	Respiratory Ventilation, Less than 24 Consecutive Hours	10000
		5A1945Z	Respiratory Ventilation, 24-96 Consecutive Hours	10000
9672	Continuous invasive mechanical ventilation for 96 consecutive hours or more	5A1955Z	Respiratory Ventilation, Greater than 96 Consecutive Hours	10000

Testing Chronic Obstructive Pulmonary Disease 30-Day Mortality and Readmission Measures in California All-Payer Data

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Introduction

The Centers for Medicare & Medicaid Services (CMS) has developed hospital 30-day risk-standardized mortality and readmission measures for patients hospitalized for chronic obstructive pulmonary disease (COPD). The measures were developed for Medicare fee-for-service (FFS) beneficiaries aged 65 years and older. The measures are currently undergoing review by the National Quality Forum (NQF). As part of the development process the measure developer, Yale New Haven Health Services Corporation/Center for Outcomes Research and Evaluation (YNHHSC/CORE), has assessed whether CMS' COPD mortality and readmission measures can be applied to and perform well in an all-payer patient population of adults aged 18 years and older. In this report, we detail our approach to addressing this question and present the findings.

The mortality and readmission measures employ administrative data, and are calculated using hierarchical logistic regression models to account for the clustering of observations within hospitals and differences in the number of admissions across hospitals. For risk adjustment, patient comorbidities are identified through claims data from each index hospitalization, and from inpatient and outpatient Medicare claims during the 12 months prior to the index hospitalization. The measure development process in the Medicare FFS population is available in the detailed methodology reports for each measure.

The results of the present analysis support expanding the COPD mortality and readmission measures' patient population to include both non-FFS Medicare patients aged 65+ years and all-payer patients aged 18-64 years. Based on the results presented below, we conclude that CMS' risk-standardized mortality and readmission rates (RSMR and RSRR) for COPD perform well when applied to all-payer data (all patients aged 18+ years). For each measure, model testing demonstrated both strong patient-level model performance and consistent hospital-level results.

Methods

Data Source: For our analyses, we used 2006 all-payer data from California in addition to 2007 CMS data for Medicare FFS 65+ patients in California hospitals. California is a diverse state, and, with more than 37 million residents, California represents 12% of the US population. We used the California Patient Discharge Data, a large, linked database of patient hospital admissions. In 2006, there were approximately 3 million adult discharges from more than 450 non-Federal acute care hospitals. Records are linked by a unique patient identification number, allowing us to determine patient history from previous hospitalizations and to evaluate rates of both readmission and mortality (via linking with California vital statistics records).

Using all-payer data from California as well as CMS Medicare FFS data for California hospitals, we performed analyses to determine whether the COPD measures can be applied to all adult patients, including FFS Medicare patients aged 65+, non-FFS Medicare patients aged 65+, and patients aged 18-64 years at the time of admission. The COPD models developed in Medicare FFS 65+ patients use inpatient and outpatient data for risk adjustment (consistent with CMS' publicly reported mortality and

readmission measures for acute myocardial infarction (AMI), heart failure (HF), and pneumonia[1-6]). To determine whether the measures can be used in all-payer data, we addressed the following questions:

Question 1: Given that outpatient claims are not available in the all-payer dataset, how do the current CMS models perform when using only admission claims data (i.e., hospital claims for admitted patients)? That is, does the exclusion of outpatient claims data adversely affect measure performance and results at the patient level and at the hospital level?

Question 2: When applied to all patients 18+, do the models perform well both at the patient level and at the hospital level? That is, at the patient level, do the models, when derived in the full 18+ population, have good discrimination, predictive ability, and model fit across patient subgroups? In addition, when new patients are added, do potential differences in the effect of risk factors across patient subgroups affect risk prediction at the patient level and risk profiling at the hospital level?

Question 1 analyses: Limiting risk-adjustment data to inpatient claims

To address the question of how the models perform when using only admission claims data, we used CMS data on FFS 65+ patients from California hospitals. Specifically, we created 2007 measure cohorts with complete one-year history data and 30-day follow-up data. For both measures, we:

A. Examined the frequency (prevalence) of risk factors using all Part B, hospital outpatient history, and admission claims (history and current) according to current CMS model specifications vs. using only admission claims data (history and current).
B. Fit the model separately using all patient history data and using only admission claims data and: (i) compared the odds ratios (ORs) for the various risk factors produced using the two different risk-adjustment datasets – the dataset using all CMS measure data sources and the admission claims only dataset; (ii) determined the value of the outpatient history information using reclassification analysis to determine the number of patients reclassified and the calibration of the predictions at the patient level; (iii) compared model performance in terms of the c-statistic (discrimination) using the two different risk-adjustment datasets; and (iv) compared hospital-level risk-standardized rates (scatterplot and intra-class correlation coefficient [ICC]) to quantify the relationship and reliability of models with and without outpatient claims history data.

Question 2 analyses: Can the models be used in all-payer patient population of adults 18 years and older?

To address the main question of how well the models perform when applied to all patients 18+, we used the California Patient Discharge Data. Specifically, using 2006 data, we created measure cohorts with up to one year of hospital admission claims history and 30-day follow-up data. For both measures, we:

A. Created the patient cohort using the CMS measure inclusion and exclusion criteria (with the exceptions of including all patients 18+ and dropping the hospice exclusion for the

mortality measures), and compared the FFS 65+, non-FFS 65+, and 18-64 year-old patient subgroups with respect to the distribution of risk factors and the crude outcome rate.

B. Fit the model in all patients 18+ and: (i) examined overall model performance in terms of the c-statistic; (ii) compared performance (c-statistic, predictive ability) across the patient subgroups (FFS 65+, non-FFS 65+, all 65+, and all-payer 18-64); and (iii) compared the distribution of Pearson residuals (model fit) across the patient subgroups.

C. Fit the model separately in each patient subgroup and compared ORs associated with the risk factors to assess differences in magnitude or direction of ORs among the subgroups.

To determine whether the relationship between each risk factor and the outcome differed for those aged 65+ vs. 18-64 in ways that would affect measure results, we:

D. Fit the model in all patients 18+ and tested interaction terms between age (65+ vs. 18-64) and each of the other risk factors.

E. Fit the model in all patients 18+ with interaction terms and compared performance (c-statistic, predictive ability) across the patient subgroups.

F. Fit the model in all patients 18+ with and without interaction terms and (i) conducted a reclassification analysis to compare risk prediction at the patient level; (ii) compared the c-statistic; and (iii) compared hospital-level risk-standardized rates (scatterplot and ICC) to assess whether the model with interactions is statistically different from the current model in profiling hospital rates.

All patient-level models were estimated using a logistic regression model; next, hospital-level RSMR and RSRR analyses were conducted using a hierarchical logistic regression model approach.

Results

Question 1 analyses: Limiting risk-adjustment data to inpatient claims

A. The numbers of patients in the COPD mortality and readmission cohorts are presented in Figure 1a-Figure 1b, respectively. For both measures, the prevalence of most risk factors was lower when using only admission claims data (Table 1a-Table 1b).

B. However, the magnitude of effect for most risk factors was similar when comparing the model using all patient history data with the model using only admission claims data Table 2a-Table 2b). In addition, when comparing the model with full data with the model with only admission claims data, the reclassification analysis demonstrated good patient-level risk prediction: for both measures, over 95% of patients were in a similar risk category (defined as being in the same or adjacent category) regardless of risk-adjustment dataset, and the integrated discrimination improvement (IDI) values were relatively low (Table 3a-

Table 3b). For both measures, the c-statistic was also qualitatively similar between the two approaches (0.719 vs. 0.722 for COPD mortality and 0.628 vs. 0.623 for COPD readmission) (Table 4a- Table 4b). Moreover, when comparing the model with full data with a model using only admission claims data, hospital-level risk-standardized rates were highly correlated for COPD mortality (ICC=0.986) and COPD readmission (ICC=0.978) (Figure 2a-Figure 2b)

Question 2 analyses: Can the models be used in all-payer patient population of adults 18 years and older?

A. The COPD mortality and readmission cohorts are presented in Figure 3a-Figure 3brespectively. As the results in Table 5a-Table 5b, for each measure, there are some differences in the risk factor profile and crude outcome rate among patient subgroups. In general, the prevalence of risk factors was similar in FFS 65+ and non-FFS 65+ patients. When comparing risk factor prevalence estimates between those 65+ and younger patients aged 18-64, frequencies were generally either lower in the younger cohort or similar between the groups. For some risk factors, including history of mechanical ventilation, sleep apnea, and psychiatric and substance use disorders, prevalence estimates were in fact higher in younger than in older patients (Table 5a-Table 5b). As expected, the crude mortality rate was substantially lower in the younger cohort (Table 5a); however, crude readmission rates were nearly identical across the patient subgroups (Table 5b).
B. Nevertheless, when the current models were applied to all patients 18+, overall discrimination was good (C statistic=0.744 for COPD mortality and 0.669 for COPD readmission) (Table 6a-Table 6b) There was also good discrimination and predictive ability in all subgroups of patients (Table 7a-Table 7b). For the COPD readmission measure, predictive ability was observed to be greater in newly added younger patients aged 18-64 years than those aged 65+ years; in addition, the C statistic was significantly higher in younger patients than in older patients (Table 7b). Moreover, for both measures, the distribution of Pearson residuals was comparable across the patient subgroups (Table 8a-Table 8b)
C. For both measures, ORs were generally similar for FFS 65+ and non-FFS 65+ patients. For some risk factors, there were differences in magnitude of effect between younger and older patients (Table 9a-Table 9b)
D. For each measure, few significant age-by-risk-factor interaction terms were found (Table 10a-Table 10b)
E. Nevertheless, inclusion of the interaction terms did not substantively change the level of discrimination and predictive ability across the patient subgroups (Table 11a-Table 11b).
F. In addition, when comparing patient risk classifications for each measure with and without interaction terms, the reclassification analysis demonstrated good patient-level risk prediction across measures: for all measures and all patient subgroups, nearly 100% of

patients were in a similar risk category (defined as being in the same or adjacent category) regardless of risk-adjustment strategy, and the IDI values were relatively small in magnitude (Table 12a-Table 12b) Moreover, the C statistic was nearly identical with and without interaction terms (0.747 vs. 0.744, respectively, for COPD mortality and 0.673 vs. 0.669, respectively, for COPD readmission) (Table 13a-Table 13b). Finally, when comparing each measure with and without interaction terms, the hospital-level risk-standardized rates estimated by the two models were highly correlated (ICC=0.999 for COPD mortality and ICC=0.991 for COPD readmission)(Figure 4a-Figure 4b).

Conclusions

Based on the results presented above, we conclude that CMS' COPD mortality and readmission measures perform well when applied to all-payer data (all patients aged 18+ years). Although there are some statistically significant age-by-risk-factor interaction terms, we do not recommend changing the model variables (with the exception of the slight modification of changing "age-65" to fully continuous age), as the inclusion of the interactions did not substantively affect either patient-level model performance or hospital-level results. We have demonstrated that the models can be applied to all patients aged 18+ years and that they perform well when using only admission claims data to determine patient history. Thus, based on these results, the measure specifications could be modified to include the 18+ population and to allow for the use of admission claims only for risk adjustment when complete claims history (i.e., outpatient data) is unavailable.

The California Patient Discharge Data have some limitations. Data on previous admissions and 30-day readmissions are available only from California hospitals; however, it is unlikely that a high proportion of patients sought hospital inpatient care outside the state given that relatively few California residents live in cities bordering other U.S. states. Likewise, linked data on 30-day mortality outside the hospital are available only for deaths in California. Moreover, although we were able to test how the measures perform without the use of outpatient data for risk adjustment in the FFS Medicare 65+ population, we were not able to do the same for non-FFS Medicare 65+ patients and younger patients aged 18-64 years given the lack of outpatient claims in the all-payer hospital discharge database. However, had the testing been possible, it is unlikely to have altered the conclusions, as all other testing demonstrated comparability between FFS Medicare and non-FFS Medicare patients aged 65+ years. In addition, given the generally lower rates of health care utilization in younger adults, lack of outpatient claims for those aged 18-64 years would be less likely to have substantively affected their subgroup results than for those aged 65+ years.

In summary, CMS' COPD measures – hospital 30-day RSMR and RSRR for COPD – perform well when used in all-payer data (all patients aged 18+ years). For each measure, model testing demonstrated both strong patient-level model performance and consistent hospital-level results.

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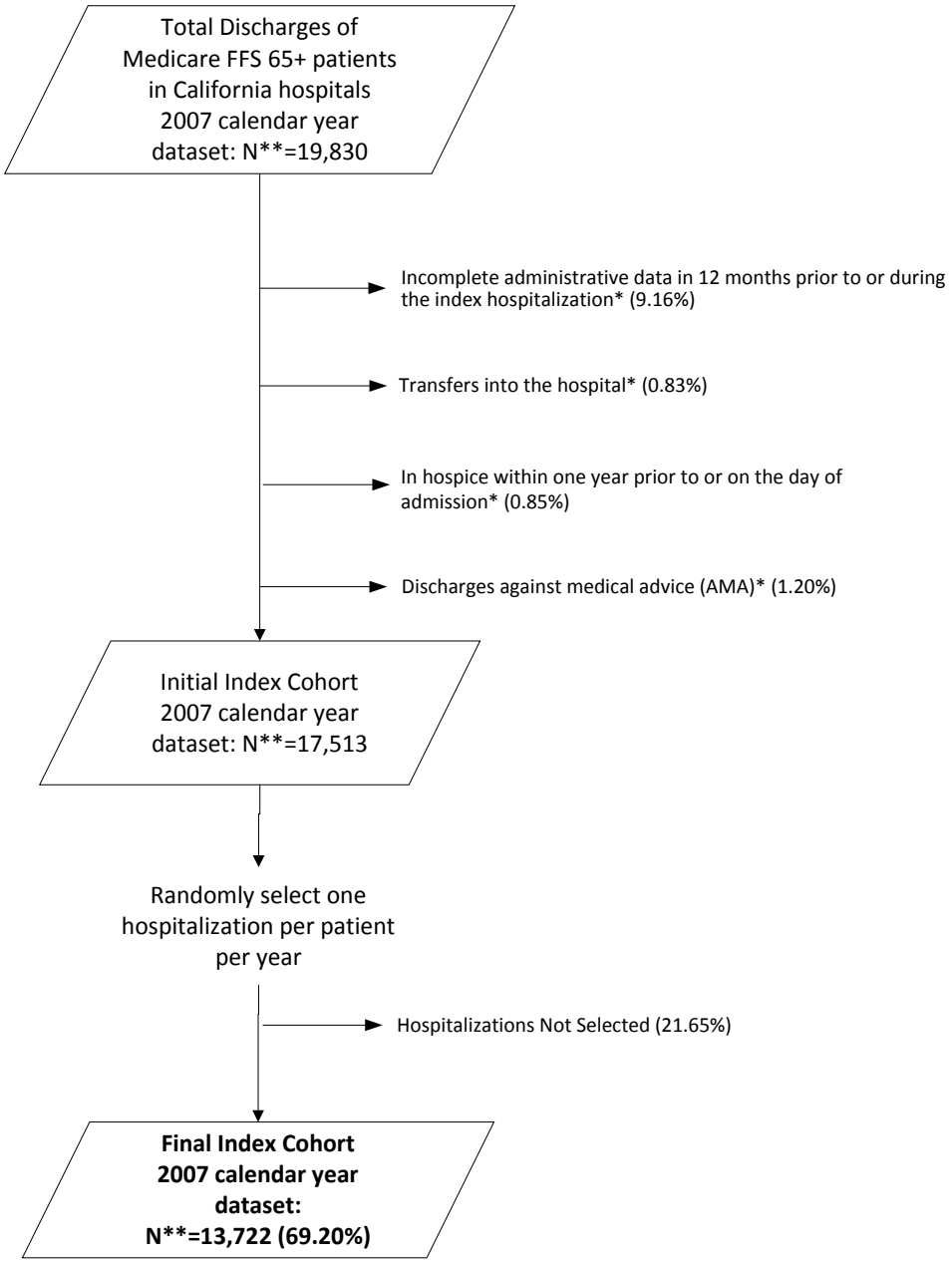
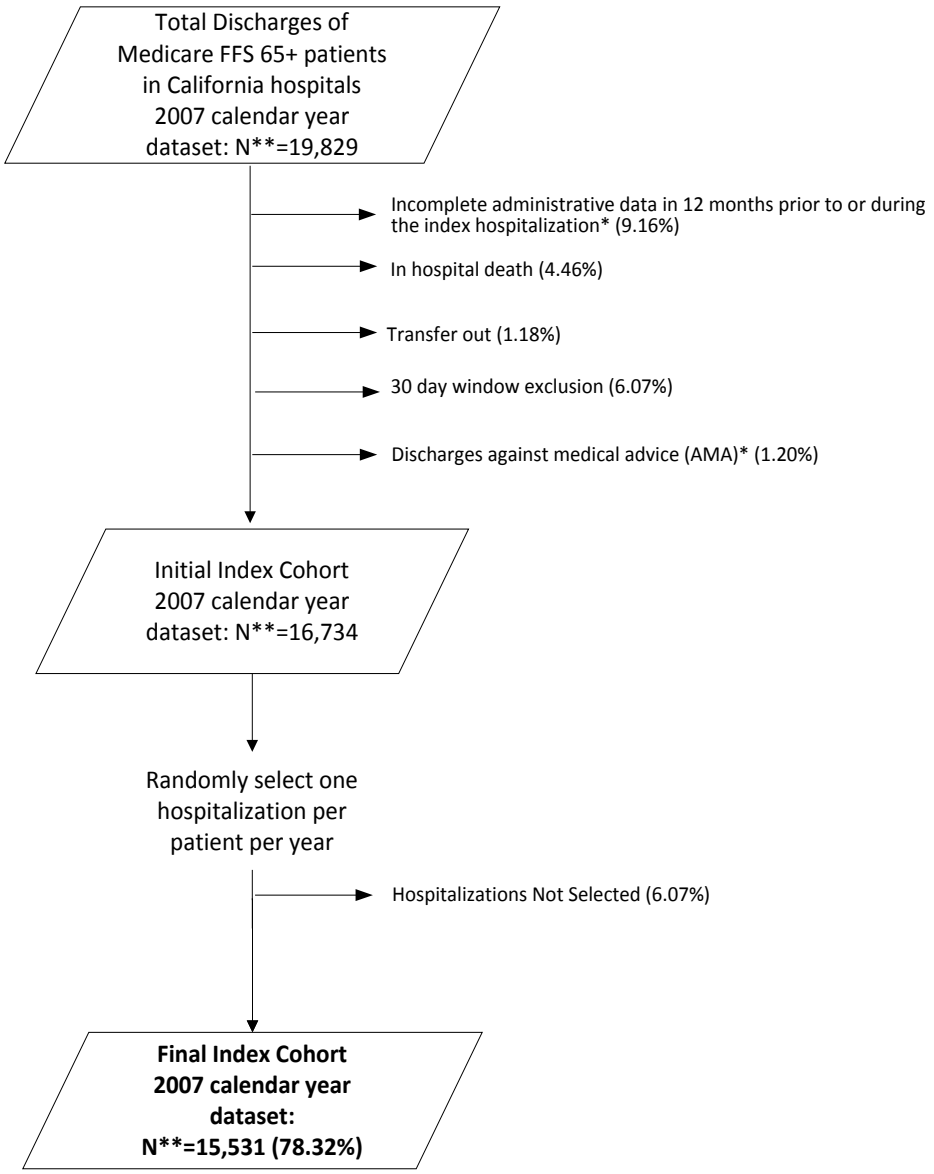
Figure 1a. 2007 COPD Mortality Cohort Using CMS Medicare Claims Data for FFS Patients 65+ Admitted to California Hospitals



*Categories are not mutually exclusive

**N refers to the number of discharges

Figure 1b.2007 COPD Readmission Cohort Using CMS Medicare Claims Data for FFS Patients 65+ Admitted to California Hospitals



*Categories are not mutually exclusive

**N refers to the number of discharges

Table 1a. Prevalence of Risk Factors for COPD Mortality Model Using Full Data vs. Using Only Admission Claims Data (N=13,722)

Data Source: 2007 CMS Medicare Claims Data for FFS Patients 65+ Admitted to California Hospitals

Risk Factor	Full data*	Admission claims data only**
	# (%)	# (%)
Demographics		
Age-65 (continuous) – Mean (std deviation)	77.92(7.58)	
Cardiovascular/Respiratory		
Sleep Apnea (ICD-9 codes: 327.20, 327.21, 327.23, 327.27, 327.29, 780.51, 780.53, 780.57)	934 (7)	634 (5)
History of Mechanical Ventilation (ICD-9 codes: 93.90, 96.70, 96.71, 96.72)	1,087 (8)	1,087 (8)
Respirator Dependence/Respiratory Failure (CC 77-78)	251 (2)	66 (0.5)
Cardio-Respiratory Failure and Shock (CC 79)	4,111 (30)	2,445 (18)
Congestive Heart Failure (CC 80)	6,200 (45)	3,645 (27)
Chronic Atherosclerosis (CC 83-84)	6,546 (48)	4,829 (35)
Arrhythmias (CC 92-93)	5,574 (41)	2,917 (21)
Vascular or Circulatory Disease (CC 104-106)	4,786 (35)	1,616 (12)
Fibrosis of Lung and Other Chronic Lung Disorder (CC 109)	2,700 (20)	1,155 (8)
Asthma (CC 110)	3,203 (23)	474 (3)
Pneumonia (CC 111-113)	6,609 (48)	4,674 (34)
Pleural Effusion/Pneumothorax (CC 114)	1,666 (12)	394 (3)
Other Lung Disorders (CC 115)	7,182 (52)	2,109 (15)
Other Comorbid Conditions		
Metastatic Cancer and Acute Leukemia (CC 7)	402 (3)	280 (2)
Lung, Upper Digestive Tract, and Other Severe Cancers (CC 8)	791 (6)	469 (3)
Lymphatic, Head and Neck, Brain, and Other Major Cancers; Breast, Prostate, Colorectal and Other Cancers and Tumors; Other Respiratory and Heart Neoplasms (CC 9-11)	1,847 (13)	591 (4)
Other Digestive and Urinary Neoplasms(CC 12)	951 (7)	206 (2)
Diabetes and DM Complications (CC 15-20, 119-120)	5,027 (37)	3,764 (27)
Protein-calorie Malnutrition (CC 21)	1,090 (8)	983 (7)
Disorders of Fluid/Electrolyte/Acid-Base (CC 22-23)	4,662 (34)	3,558 (26)
Other Endocrine/Metabolic/Nutritional Disorders (CC 24)	8,768 (64)	6,263 (46)
Other Gastrointestinal Disorders (CC 36)	7,275 (53)	4,423 (32)
Osteoarthritis of Hip or Knee (CC 40)	1,223 (9)	289 (2)
Other Musculoskeletal and Connective Tissue Disorders (CC 43)	8,900 (65)	3,263 (24)
Iron Deficiency and Other/Unspecified Anemias and Blood Disease (CC 47)	5,895 (43)	3,999 (29)
Dementia and Senility (CC 49-50)	2,475 (18)	1,642 (12)
Drug/Alcohol Abuse, Without Dependence (CC 53)	3,145 (23)	2,763 (20)
Other Psychiatric Disorders (CC 60)	1,859 (14)	1,197 (9)
Quadriplegia, Paraplegia, Functional Disability (CC 67-69, 100-102, 177-178)	779 (6)	342 (2)
Mononeuropathy, Other Neurological Conditions/Injuries (CC 76)	1,434 (10)	536 (4)
Hypertension and Hypertensive Disease (CC 90-91)	10,795 (79)	8,300 (60)
Stroke (CC 95-96)	1,066 (8)	212 (2)
Retinal Disorders, Except Detachment and Vascular Retinopathies (CC 121)	1,431 (10)	130 (1)

Risk Factor	Full data*	Admission claims data only**
	# (%)	# (%)
Other Eye Disorders (CC 124)	3,028 (22)	177 (1)
Other Ear, Nose, Throat, and Mouth Disorders (CC 127)	4,387 (32)	831 (6)
Renal Failure (CC 131)	2,453 (18)	1,755 (13)
Decubitus Ulcer or Chronic Skin Ulcer (CC 148-149)	1,082 (8)	482 (4)
Other Dermatological Disorders (CC 153)	5,138 (37)	298 (2)
Trauma (CC 154-156, 158-161)	1,251 (9)	483 (4)
Vertebral Fractures (CC 157)	772 (6)	440 (3)
Major Complications of Medical Care and Trauma (CC 164)	762 (6)	380 (3)

* Including Part B, hospital outpatient, and hospital inpatient data.
** for both index admission and admissions in the past 12 months.

Table 1b. Prevalence of Risk Factors for COPD Readmission Model Using Full Data vs. Using Only Admission Claims Data (N=15,531)

Data Source: 2007 CMS Medicare Claims Data for FFS Patients 65+ Admitted to California Hospitals

Risk Factor	Full data*	Admission claims data only**
	# (%)	# (%)
Demographics		
Age-65 (continuous) – mean (std deviation)	77.64 (7.54)	
Cardiovascular/Respiratory		
Sleep Apnea (ICD-9 codes: 327.20, 327.21, 327.23, 327.27, 327.29, 780.51, 780.53, 780.57)	1,149 (7)	794 (5)
History of Mechanical Ventilation (ICD-9 codes: 93.90, 96.70, 96.71, 96.72)	1,430 (9)	1,430 (9)
Respirator Dependence/Respiratory Failure (CC 77-78)	292 (2)	70 (0.5)
Cardio-Respiratory Failure and Shock (CC 79)	5,117 (33)	3,154 (20)
Congestive Heart Failure (CC 80)	7,254 (47)	4,408 (28)
Chronic Atherosclerosis (CC 83-84)	7,625 (49)	5,739 (37)
Arrhythmias (CC 92-93)	6,454 (42)	3,455 (22)
Other and Unspecified Heart Disease (CC 94)	3,395 (22)	572 (4)
Vascular or Circulatory Disease (CC 104-106)	5,551 (36)	1,953 (13)
Fibrosis of Lung and Other Chronic Lung Disorder (CC 109)	3,220 (21)	1,358 (9)
Pneumonia (CC 111-113)	7,671 (49)	5,416 (35)
Other Comorbid Conditions		
History of Infection (CC 1, 3-6)	4,949 (32)	1,681 (11)
Metastatic Cancer and Acute Leukemia (CC 7)	402 (3)	274 (2)
Lung, Upper Digestive Tract, and Other Severe Cancers (CC 8)	843 (5)	490 (3)
Lymphatic, Head and Neck, Brain, and Other Major Cancers; Breast, Prostate, Colorectal and Other Cancers and Tumors; Other Respiratory and Heart Neoplasms (CC 9-11)	2,021 (13)	667 (4)
Other Digestive and Urinary Neoplasms(CC 12)	1,084 (7)	256 (2)
Diabetes and DM Complications (CC 15-20, 119-120)	5,840 (38)	4,427 (29)
Protein-calorie Malnutrition (CC 21)	1,186 (8)	1,073 (7)
Disorders of Fluid/Electrolyte/Acid-Base (CC 22-23)	5,586 (36)	4,387 (28)
Other Endocrine/Metabolic/Nutritional Disorders (CC 24)	10,000 (64)	7,318 (47)
Pancreatic Disease (CC 32)	744 (5)	614 (4)
Peptic Ulcer, Hemorrhage, Other Specified Gastrointestinal Disorders (CC 34)	2,067 (13)	1,094 (7)
Other Gastrointestinal Disorders (CC 36)	8,537 (55)	5,359 (35)
Severe Hematological Disorders (CC 44)	368 (2)	153 (1)
Iron Deficiency and Other/Unspecified Anemias and Blood Disease (CC 47)	6,851 (44)	4,768 (31)
Dementia and Senility (CC 49-50)	2,760 (18)	1,829 (12)
Drug/Alcohol Induced Dependence/Psychosis (CC 51-52)	790 (5)	700 (5)
Major Psych Disorders (CC 54-56)	1,854 (12)	894 (6)
Depression (CC 58)	2,671 (17)	2,060 (13)
Anxiety Disorders (CC 59)	362 (2)	142 (1)
Other Psychiatric Disorders (CC 60)	2,367 (15)	1,582 (10)
Quadriplegia, Paraplegia, Functional Disability (CC 67-69, 100-102, 177-178)	882 (6)	395 (3)
Polyneuropathy (CC 71)	1,055 (7)	554 (4)

Risk Factor	Full data*	Admission claims data only**
	# (%)	# (%)
Acute Coronary Syndrome (CC 81-82)	1,723 (11)	814 (5)
Hypertensive Heart and Renal Disease or Encephalopathy (CC 89)	1,478 (10)	1,353 (9)
Stroke (CC 95-96)	1,182 (8)	247 (2)
Renal Failure (CC 131)	2,781 (18)	2,034 (13)
Decubitus Ulcer or Chronic Skin Ulcer (CC 148-149)	1,218 (8)	554 (4)
Cellulitis, Local Skin Infection (CC 152)	2,212 (14)	650 (4)
Vertebral Fractures (CC 157)	918 (6)	526 (3)

* Including Part B, hospital outpatient, and hospital inpatient data.
** for both index admission and admissions in the past 12 months.

Table 2a. Odds Ratios for Risk Factors in COPD Mortality Models With Full Data and With Only Admission Claims Data -- Logistic Regression Model (N=13,722)

Data Source: 2007 CMS Medicare Claims Data for FFS Patients 65+ Admitted to California Hospitals

Risk Factor	Full data*	Admission claims data only**
	OR (95% CI)	OR (95% CI)
Demographics		
Age-65 (continuous)	1.03 (1.02-1.04)	1.03 (1.02-1.04)
Cardiovascular/Respiratory		
Sleep Apnea (ICD-9 codes: 327.20, 327.21, 327.23, 327.27, 327.29, 780.51, 780.53, 780.57)	0.84 (0.65-1.09)	0.74 (0.54-1.03)
History of Mechanical Ventilation (ICD-9 codes: 93.90, 96.70, 96.71, 96.72)	1.24 (1.01-1.52)	1.17 (0.94-1.45)
Respirator Dependence/Respiratory Failure (CC 77-78)	0.97 (0.67-1.42)	1.07 (0.53-2.14)
Cardio-Respiratory Failure and Shock (CC 79)	1.40 (1.22-1.62)	1.46 (1.23-1.74)
Congestive Heart Failure (CC 80)	1.21 (1.06-1.39)	1.29 (1.10-1.50)
Chronic Atherosclerosis (CC 83-84)	0.93 (0.82-1.06)	0.84 (0.74-0.95)
Arrhythmias (CC 92-93)	1.14 (1.00-1.30)	1.32 (1.14-1.53)
Vascular or Circulatory Disease (CC 104-106)	1.09 (0.95-1.24)	1.12 (0.94-1.34)
Fibrosis of Lung and Other Chronic Lung Disorder (CC 109)	1.07 (0.93-1.24)	1.32 (1.10-1.59)
Asthma (CC 110)	0.63 (0.54-0.74)	0.50 (0.33-0.77)
Pneumonia (CC 111-113)	1.52 (1.34-1.74)	1.57 (1.38-1.79)
Pleural Effusion/Pneumothorax (CC 114)	1.18 (1.00-1.39)	0.93 (0.69-1.26)
Other Lung Disorders (CC 115)	0.84 (0.74-0.95)	0.78 (0.66-0.93)
Other Comorbid Conditions		
Metastatic Cancer and Acute Leukemia (CC 7)	3.06 (2.32-4.05)	3.29 (2.39-4.52)
Lung, Upper Digestive Tract, and Other Severe Cancers (CC 8)	1.58 (1.26-1.98)	2.07 (1.59-2.69)
Lymphatic, Head and Neck, Brain, and Other Major Cancers; Breast, Prostate, Colorectal and Other Cancers and Tumors; Other Respiratory and Heart Neoplasms (CC 9-11)	1.01 (0.85-1.20)	1.07 (0.82-1.38)
Other Digestive and Urinary Neoplasms(CC 12)	0.83 (0.65-1.07)	1.23 (0.77-1.97)
Diabetes and DM Complications (CC 15-20, 119-120)	0.88 (0.78-1.01)	0.86 (0.74-0.99)
Protein-calorie Malnutrition (CC 21)	2.15 (1.82-2.54)	2.19 (1.85-2.61)
Disorders of Fluid/Electrolyte/Acid-Base (CC 22-23)	1.04 (0.91-1.20)	1.01 (0.87-1.17)
Other Endocrine/Metabolic/Nutritional Disorders (CC 24)	0.87 (0.77-0.99)	0.81 (0.71-0.91)
Other Gastrointestinal Disorders (CC 36)	0.89 (0.79-1.01)	0.81 (0.71-0.92)
Osteoarthritis of Hip or Knee (CC 40)	0.70 (0.54-0.89)	0.47 (0.27-0.83)
Other Musculoskeletal and Connective Tissue Disorders (CC 43)	0.88 (0.78-1.00)	0.87 (0.75-1.01)
Iron Deficiency and Other/Unspecified Anemias and Blood Disease (CC 47)	0.94 (0.83-1.07)	0.90 (0.79-1.03)
Dementia and Senility (CC 49-50)	1.12 (0.97-1.30)	1.16 (0.98-1.37)
Drug/Alcohol Abuse, Without Dependence (CC 53)	0.84 (0.72-0.98)	0.85 (0.73-1.00)
Other Psychiatric Disorders (CC 60)	0.94 (0.79-1.12)	0.89 (0.71-1.11)

Risk Factor	Full data*	Admission claims data only**
	OR (95% CI)	OR (95% CI)
Quadriplegia, Paraplegia, Functional Disability (CC 67-69, 100-102, 177-178)	0.99 (0.77-1.26)	1.18 (0.83-1.67)
Mononeuropathy, Other Neurological Conditions/Injuries (CC 76)	0.92 (0.76-1.13)	0.68 (0.48-0.95)
Hypertension and Hypertensive Disease (CC 90-91)	0.72 (0.63-0.83)	0.74 (0.66-0.84)
Stroke (CC 95-96)	1.08 (0.88-1.34)	1.13 (0.73-1.74)
Retinal Disorders, Except Detachment and Vascular Retinopathies (CC 121)	0.98 (0.81-1.19)	1.16 (0.67-2.01)
Other Eye Disorders (CC 124)	0.83 (0.72-0.97)	1.03 (0.64-1.67)
Other Ear, Nose, Throat, and Mouth Disorders (CC 127)	0.81 (0.71-0.93)	0.63 (0.47-0.85)
Renal Failure (CC 131)	1.12 (0.96-1.30)	1.05 (0.88-1.26)
Decubitus Ulcer or Chronic Skin Ulcer (CC 148-149)	1.21 (0.99-1.47)	1.22 (0.93-1.58)
Other Dermatological Disorders (CC 153)	0.85 (0.75-0.96)	0.95 (0.63-1.42)
Trauma (CC 154-156, 158-161)	1.21 (1.01-1.46)	1.24 (0.94-1.64)
Vertebral Fractures (CC 157)	1.22 (0.97-1.54)	1.25 (0.94-1.67)
Major Complications of Medical Care and Trauma (CC 164)	0.99 (0.78-1.25)	1.05 (0.76-1.44)

* Including Part B, hospital outpatient, and hospital inpatient data.

** for both index admission and admissions in the past 12 months.

Table 2b. Odds Ratios for Risk Factors in COPD Readmission Models With Full Data and With Only Admission Claims Data -- Logistic Regression Model (N=15,531)

Data Source: 2007 CMS Medicare Claims Data for FFS Patients 65+ Admitted to California Hospitals

Risk Factor	Full data*	Admission claims data only**
	OR (95% CI)	OR (95% CI)
Demographics		
Age-65 (continuous)	1.00 (0.99-1.00)	1.00 (1.00-1.01)
Cardiovascular/Respiratory		
Sleep Apnea (ICD-9 codes: 327.20, 327.21, 327.23, 327.27, 327.29, 780.51, 780.53, 780.57)	0.83 (0.71-0.97)	0.84 (0.70-1.01)
History of Mechanical Ventilation (ICD-9 codes: 93.90, 96.70, 96.71, 96.72)	1.12 (0.97-1.28)	1.10 (0.95-1.28)
Respirator Dependence/Respiratory Failure (CC 77-78)	0.90 (0.69-1.18)	0.89 (0.53-1.52)
Cardio-Respiratory Failure and Shock (CC 79)	1.17 (1.06-1.29)	1.09 (0.98-1.23)
Congestive Heart Failure (CC 80)	1.15 (1.05-1.26)	1.25 (1.13-1.38)
Chronic Atherosclerosis (CC 83-84)	1.15 (1.05-1.25)	1.16 (1.07-1.27)
Arrhythmias (CC 92-93)	1.14 (1.04-1.24)	1.14 (1.03-1.26)
Other and Unspecified Heart Disease (CC 94)	1.09 (0.99-1.20)	0.90 (0.74-1.11)
Vascular or Circulatory Disease (CC 104-106)	1.01 (0.93-1.10)	1.09 (0.97-1.23)
Fibrosis of Lung and Other Chronic Lung Disorder (CC 109)	1.15 (1.04-1.26)	1.26 (1.11-1.43)
Pneumonia (CC 111-113)	1.21 (1.11-1.31)	1.17 (1.08-1.28)
Other Comorbid Conditions		
History of Infection (CC 1, 3-6)	1.14 (1.04-1.24)	1.21 (1.08-1.37)
Metastatic Cancer and Acute Leukemia (CC 7)	1.17 (0.91-1.50)	1.22 (0.91-1.64)
Lung, Upper Digestive Tract, and Other Severe Cancers (CC 8)	1.30 (1.09-1.55)	1.33 (1.07-1.66)
Lymphatic, Head and Neck, Brain, and Other Major Cancers; Breast, Prostate, Colorectal and Other Cancers and Tumors; Other Respiratory and Heart Neoplasms (CC 9-11)	1.05 (0.94-1.19)	1.16 (0.96-1.39)
Other Digestive and Urinary Neoplasms(CC 12)	0.92 (0.79-1.08)	1.09 (0.82-1.45)
Diabetes and DM Complications (CC 15-20, 119-120)	1.05 (0.97-1.14)	1.03 (0.94-1.13)
Protein-calorie Malnutrition (CC 21)	1.06 (0.92-1.22)	1.09 (0.94-1.26)
Disorders of Fluid/Electrolyte/Acid-Base (CC 22-23)	1.16 (1.06-1.27)	1.11 (1.01-1.22)
Other Endocrine/Metabolic/Nutritional Disorders (CC 24)	0.85 (0.78-0.93)	0.93 (0.86-1.01)
Pancreatic Disease (CC 32)	1.21 (1.02-1.43)	1.28 (1.07-1.54)
Peptic Ulcer, Hemorrhage, Other Specified Gastrointestinal Disorders (CC 34)	1.07 (0.96-1.20)	1.09 (0.94-1.26)
Other Gastrointestinal Disorders (CC 36)	1.03 (0.94-1.12)	1.06 (0.97-1.15)
Severe Hematological Disorders (CC 44)	0.99 (0.78-1.27)	0.96 (0.67-1.39)
Iron Deficiency and Other/Unspecified Anemias and Blood Disease (CC 47)	1.12 (1.03-1.22)	1.20 (1.10-1.31)
Dementia and Senility (CC 49-50)	1.06 (0.96-1.18)	0.97 (086-1.10)
Drug/Alcohol Induced Dependence/Psychosis (CC 51-	1.26 (1.07-1.49)	1.23 (1.03-1.47)

Risk Factor	Full data*	Admission claims data only**
	OR (95% CI)	OR (95% CI)
52)		
Major Psych Disorders (CC 54-56)	0.94 (0.83-1.06)	1.14 (0.97-1.34
Depression (CC 58)	0.97 (0.87-1.08)	0.96 (0.85-1.08)
Anxiety Disorders (CC 59)	1.12 (0.88-1.43)	1.23 (0.84-1.79)
Other Psychiatric Disorders (CC 60)	1.15 (1.03-1.27)	1.07 (0.94-1.21)
Quadriplegia, paraplegia, functional disability (CC 67-69, 100-102, 177-178)	0.90 (0.76-1.06)	0.99 (0.78-1.26)
Polyneuropathy (CC 71)	1.16 (1.00-1.34)	1.21 (1.00-1.47)
Acute Coronary Syndrome (CC 81-82)	1.18 (1.05-1.33)	1.11 (0.94-1.31)
Hypertensive Heart and Renal Disease or Encephalopathy (CC 89)	1.04 (0.90-1.20)	0.99 (0.86-1.15)
Stroke (CC 95-96)	1.02 (0.88-1.18)	1.08 (0.80-1.45)
Renal Failure (CC 131)	1.03 (0.92-1.16)	1.09 (0.96-1.24)
Decubitus Ulcer or Chronic Skin Ulcer (CC 148-149)	1.10 (0.96-1.27)	1.17 (0.96-1.43)
Cellulitis, Local Skin Infection (CC 152)	1.18 (1.05-1.31)	1.19 (0.99-1.42)
Vertebral Fractures (CC 157)	1.07 (0.91-1.25)	1.28 (1.05-1.55)

* Including Part B, hospital outpatient, and hospital inpatient data.

** for both index admission and admissions in the past 12 months.

Table 3a. Reclassification Table of Risk Categories for COPD Mortality Model with Full Data and With Only Admission Claims Data

Data Source: 2007 CMS Medicare Claims Data for FFS Patients 65+ Admitted to California Hospitals

Model with Full Data*	Model with Admission Claims only Data**									
	0 to <5%		5% to <10%		10% to <20%		>=20%		Total	
	#	Column %	#	Column %	#	Column %	#	Column %	#	
Risk Category										
0 to <5%	1,996	14.55	1,223	8.91	107	0.78	0	0.0	3,326	
5% to <10%	1,162	8.47	3,454	25.17	947	6.90	35	0.26	5,598	Same category: 59.72
10% to <20%	82	0.60	1,144	8.34	1,944	14.17	399	2.91	3,569	Similar category: 97.88
>=20%	2	0.01	65	0.47	362	2.64	800	5.83	1,229	NRI= 0.021517; p-value 0.21536
Total	3,242	23.63	5,886	42.89	3,360	24.49	1,234	8.99	13,722	IDI=0.004761, p-value 0.01101.

* Including Part B, hospital outpatient, and hospital inpatient data.

** for both index admission and admissions in the past 12 months

Table 3b. Reclassification Table of Risk Categories for COPD Readmission Model with Full Data and With Only Admission Claims Data
Data Source: 2007 CMS Medicare Claims Data for FFS Patients 65+ Admitted to California Hospitals

Model with Full Data*	Model with Admission Claims Only Data**								
	0 to 15%		15% to <20%		20% to <25%		>=25%		Total
	#	Column %	#	Column %	#	Column %	#	Column %	#
Risk Category									
0 to <15%	1,550	9.98	1,348	8.68	41	0.26	0	0.00	2,393
15% to <20%	722	4.65	2,877	18.52	877	5.65	101	0.65	4,577
20% to <25%	156	1.00	1,046	6.73	1,327	8.54	752	4.84	3,281
>=25%	29	0.19	286	1.84	801	5.16	3,618	23.30	4,734
Total	2,457	15.82	5,557	35.78	3,046	19.61	4,471	28.79	15,531

Same category: 60.34
Similar category: 96.05
NRI=-0.033384; p-value 0.0044705
IDI=-0.001331, p-value 0.13249.

* Including Part B, hospital outpatient, and hospital inpatient data.
** for both index admission and admissions in the past 12 months

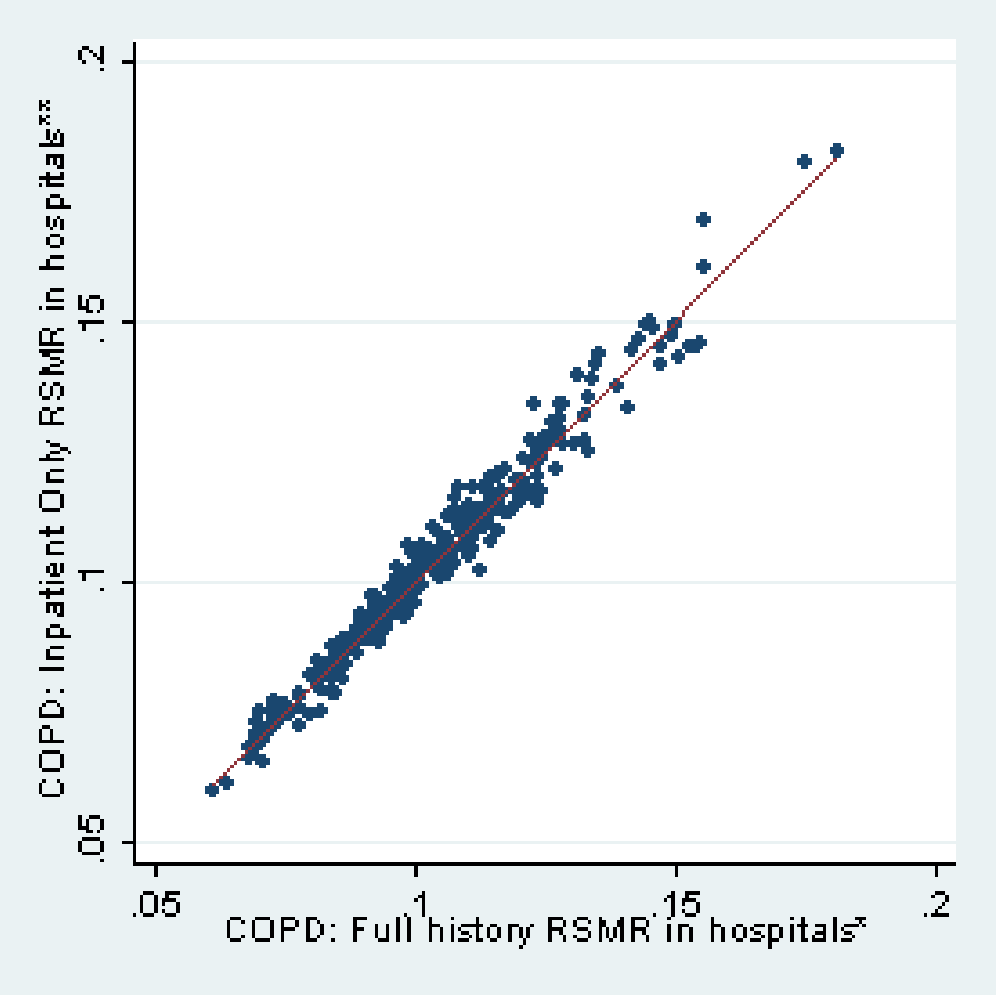
Table 4a. Performance of COPD Mortality Logistic Regression Model With Full Data and With Only Admission Claims Data

Data Source: 2007 CMS Medicare Claims Data for FFS Patients 65+ Admitted to California Hospitals

	Model with full data*	Model with admission claims data only**
C-statistic	0.719	0.722

Figure 2a. Scatterplot of COPD 30-day Risk-Standardized Mortality Rates (RSMR) from Model Using Full Data and from Model Using Only Admission Claims Data (N= 13,722)

Data Source: 2007 CMS Medicare Claims Data for FFS Patients 65+ Admitted to California Hospitals



Intra-class Correlation Coefficients (ICC): 0.986

Note: 1) RSMRs are in proportions.
2) Diagonal line represents the fitted line.

* Including Part B, hospital outpatient, and hospital inpatient data.
** for both index admission and admissions in the past 12 months.

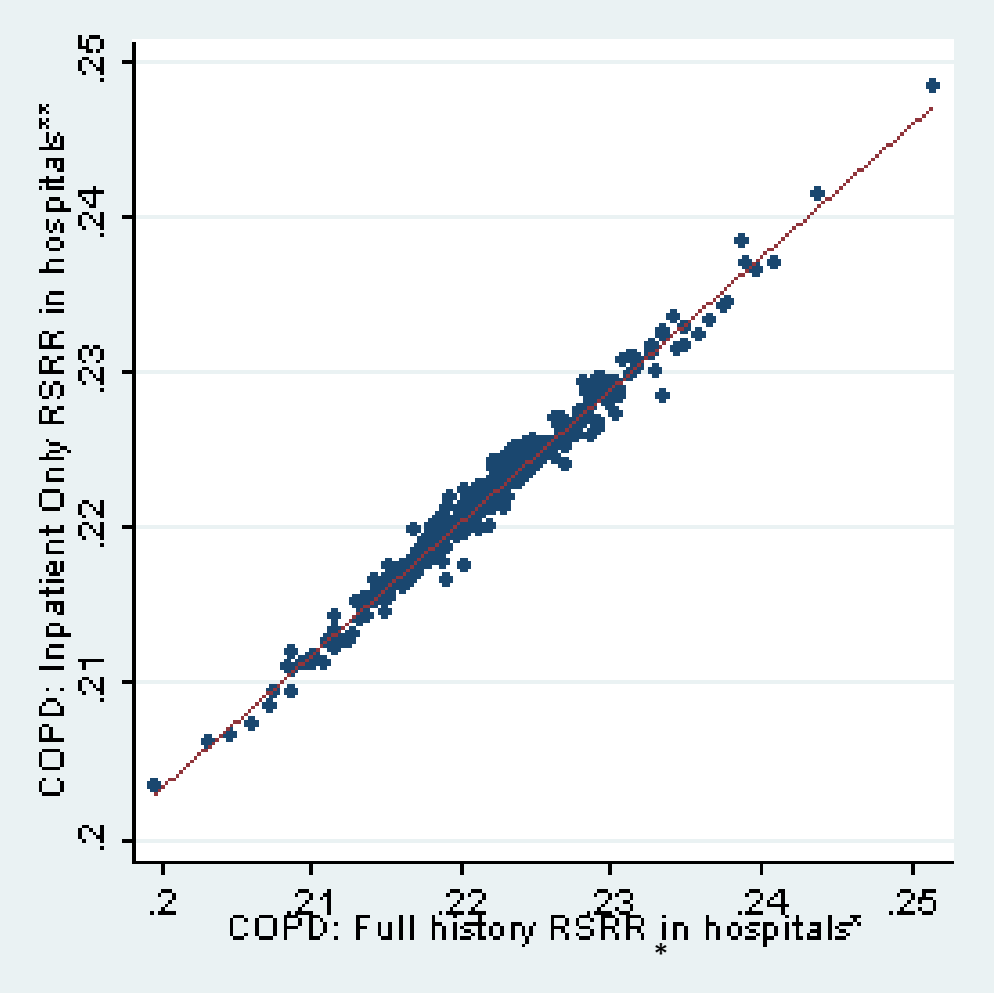
Table 4b. Performance of COPD Readmission Logistic Regression Model With Full Data and With Only Admission Claims Data

Data Source: 2007 CMS Medicare Claims Data for FFS Patients 65+ Admitted to California Hospitals

	Model with full data*	Model with admission claims data only**
C-statistic	0.628	0.623

Figure 2b. Scatterplot of COPD 30-day Risk-Standardized Readmission Rates (RSRR) from Model Using Full Data and from Model Using Only Admission Claims Data (N=15,531)

Data Source: 2007 CMS Medicare Claims Data for FFS Patients 65+ Admitted to California Hospitals

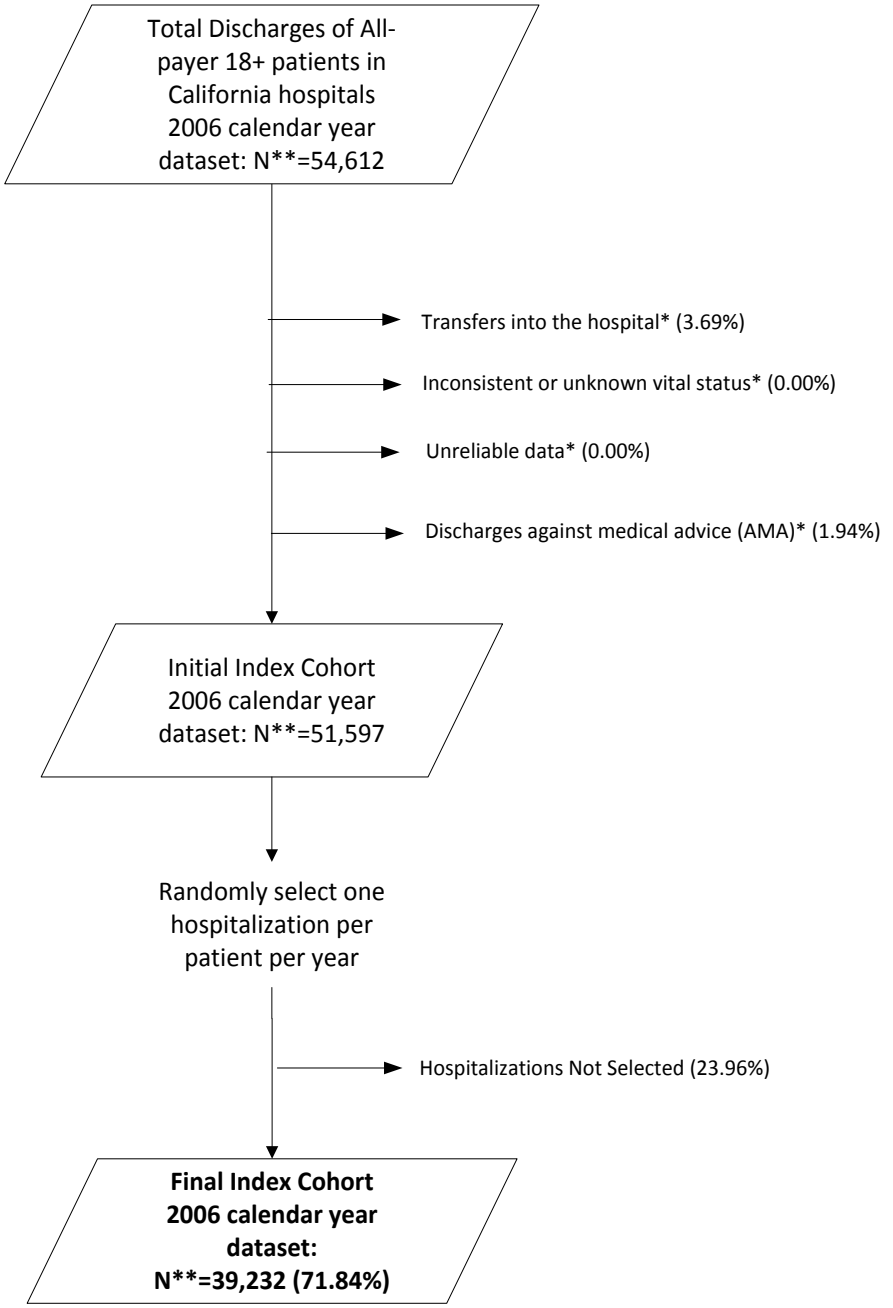


Intra-class Correlation Coefficients (ICC): 0.978

Note: 1) RSMRs are in proportions.
2) Diagonal line represents the fitted line.

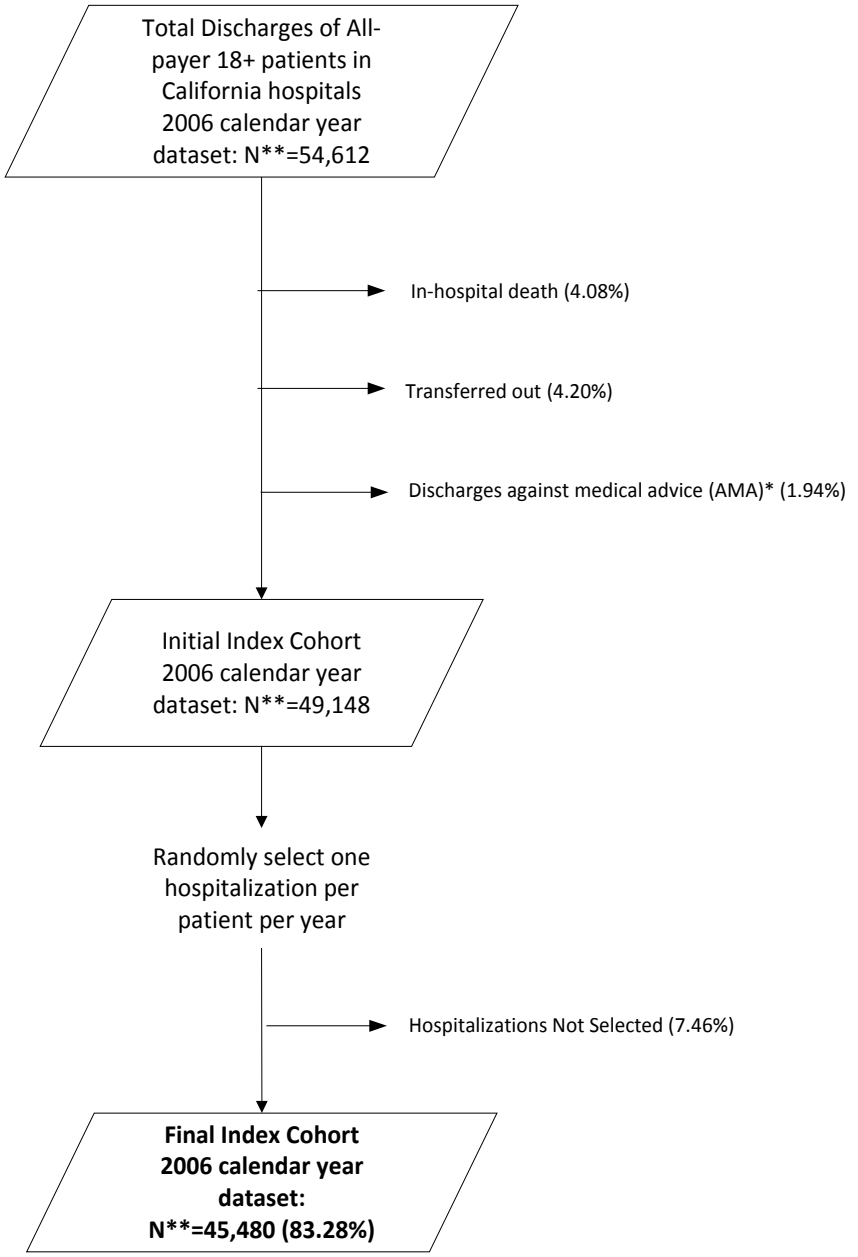
* Including Part B, hospital outpatient, and hospital inpatient data.
** for both index admission and admissions in the past 12 months.

Figure 3a. 2006 COPD Mortality Cohort Using California Patient Discharge Data for All-payer Patients 18+ Admitted to California Hospitals



*Categories are not mutually exclusive
**N refers to the number of discharges.

Figure 3b. 2006 COPD Readmission Cohort Using California Patient Discharge Data for All-payer Patients 18+ Admitted to California Hospitals



*Categories are not mutually exclusive
**N refers to the number of discharge

Table 5a. Prevalence of Risk Factors in COPD Mortality Model for All Patients Aged 18+ Years, FFS 65+ Patients, Non-FFS 65+ Patients, and All Patients 18-64 Years of Age

Data Source: 2006 California Patient Discharge Data for All-payer Patients 18+ Admitted to California Hospitals

Description	All 18+ (Total)	FFS 65+	Non-FFS 65+	Age 18- 64 Years
	# (%)	# (%)	# (%)	# (%)
All	39,232 (100)	16,629 (100)	9,917 (100)	12,686 (100)
Demographics				
Age	69.95 (13)	77.49 (8)	77.13 (7)	54.46 (8)
Cardiovascular/Respiratory				
History of Mechanical Ventilation (ICD-9 codes: 93.90, 96.70, 96.71, 96.72)	3,536 (9)	1,281 (8)	815 (8)	1,440 (11)
Sleep Apnea (ICD-9 codes: 327.20, 327.21, 327.23, 327.27, 327.29, 780.51, 780.53, 780.57)	3,259 (8)	983 (6)	548 (6)	1,728 (14)
Respirator Dependence/Respiratory Arrest (CC 77-78)	315 (1)	119 (1)	65 (1)	131 (1)
Cardio-Respiratory Failure and Shock (CC 79)	5,666 (14)	2,398 (14)	1,298 (14)	1,970 (16)
Congestive Heart Failure (CC 80)	8,884 (23)	4,322 (26)	2,221 (22)	2,341(18)
Chronic Atherosclerosis (CC 83-84)	12,705 (32)	6,572 (40)	3,397 (34)	2,736 (22)
Arrhythmias (CC 92-93)	6,696 (17)	3,453 (21)	1,944 (20)	1,299 (10)
Vascular or Circulatory Disease (CC 104-106)	4,713 (12)	2,278 (14)	1,236 (12)	1,199 (9)
Fibrosis of Lung and Other Chronic Lung Disorder (CC 109)	2,740 (7)	1,407 (8)	684 (7)	649 (5)
Asthma (CC 110)	2,417 (6)	698 (4)	343 (3)	1,376 (11)
Pneumonia (CC 111-113)	12,026 (31)	5,421 (33)	3,071 (31)	3,534 (28)
Pleural Effusion/Pneumothorax (CC 114)	931 (2)	423 (3)	255 (3)	253 (2)
Other Lung Disorders (CC 115)	6,332 (16)	2,771 (17)	1,377 (14)	2,184 (17)
Comorbidities				
Metastatic Cancer and Acute Leukemia (CC 7)	686 (2)	348 (2)	174 (2)	164 (1)
Lung, Upper Digestive Tract, and Other Severe Cancers (CC 8)	1,039 (3)	542 (3)	298 (3)	199 (2)
Lymphatic, Head and Neck, Brain, and Other Major Cancers; Breast, Colorectal and other Cancers and Tumors; Other Respiratory and Heart Neoplasms (CC 9-11)	1,577 (4)	809 (5)	465 (5)	303 (2)
Other Digestive and Urinary Neoplasms (CC 12)	628 (2)	346 (2)	130 (1)	152 (1)
Diabetes and DM Complications (CC 15-20, 119-120)	11,836 (30)	5,137 (31)	2,790 (28)	3,909 (31)
Protein-Calorie Malnutrition (CC 21)	2,556 (7)	1,286 (8)	696 (7)	574 (5)
Disorders of Fluid/Electrolyte/Acid-Base (CC 22-23)	8,623 (22)	3,945 (24)	1,970 (20)	2,708 (21)
Other Endocrine/Metabolic/Nutritional Disorders (CC 24)	19,980 (51)	8,551 (51)	5,187 (52)	6,242 (49)
Other Gastrointestinal Disorders (CC 36)	14,422 (37)	6,651 (40)	3,457 (35)	4,314 (34)

Description	All 18+ (Total)	FFS 65+	Non-FFS 65+	Age 18- 64 Years
	# (%)	# (%)	# (%)	# (%)
Osteoarthritis of Hip or Knee (CC 40)	922 (2)	461 (3)	217 (2)	244 (2)
Other Musculoskeletal and Connective Tissue Disorders (CC 43)	11,225 (29)	5,123 (31)	2,666 (27)	3,436 (27)
Iron Deficiency and Other/Unspecified Anemia and Blood Disease (CC 47)	12,284 (31)	5,901 (35)	3,143 (32)	3,240 (26)
Dementia or Senility (CC 49-50)	3,658 (9)	2,363 (14)	1,076 (11)	209 (2)
Drug/Alcohol Abuse, without Dependence (CC 53)	14,160 (36)	4,169 (25)	2,492 (25)	7,499 (59)
Other Psychiatric Disorders (CC 60)	5,059 (13)	1,962 (12)	1,186 (12)	1,911 (15)
Quadriplegia, Paraplegia, Functional Disability (CC 67-69, 100-102, 177-178)	1,322 (3)	622 (4)	306 (3)	394 (3)
Mononeuropathy, Other Neurological Conditions/Injuries (CC 76)	2,040 (5)	809 (5)	474 (5)	757 (6)
Hypertension and Hypertensive Disease (CC 90-91)	24,386 (62)	10,835 (65)	6,503 (66)	7,048 (56)
Stroke (CC 95-96)	475 (1)	244 (1)	122 (1)	109 (1)
Retinal Disorders, except Detachment and Vascular Retinopathies (CC 121)	425 (1)	238 (1)	175 (2)	12 (0)
Other Eye Disorders (CC 124)	789 (2)	347 (2)	209 (2)	233 (2)
Other Ear, Nose, Throat, and Mouth Disorders (CC 127)	3,316 (8)	1,324 (8)	730 (7)	1,262 (10)
Renal Failure (CC 131)	3,517 (9)	1,719 (10)	1,023 (10)	775 (6)
Decubitus Ulcer or Chronic Skin Ulcer (CC 148-149)	1,337 (3)	605 (4)	328 (3)	404 (3)
Other Dermatological Disorders (CC 153)	1,540 (4)	580 (3)	323 (3)	637 (5)
Trauma (CC 154-156, 158-161)	973 (2)	469 (3)	256 (3)	248 (2)
Vertebral Fractures (CC 157)	874 (2)	501 (3)	232 (2)	141 (1)
Major Complications of Medical Care and Trauma (CC 164)	1,009 (2)	432 (3)	228 (2)	349 (3)
Outcome				
Death within 30-days of admission	3,229 (8)	1,621 (10)	1,184 (12)	424 (3)

Note:

1. FFS is defined as payer category=Medicare and payer type of coverage=Traditional.
2. The distribution for all risk factors is significantly different (at the p=0.05 level) across subgroups Except “Other Eye Disorders” and “Decubitus Ulcer or Chronic Skin Ulcer”

Table 5b. Prevalence of Risk Factors in COPD Readmission Model for All Patients Aged 18+ Years, FFS 65+ Patients, Non-FFS 65+ Patients, and All Patients 18-64 Years of Age

Data Source: 2006 California Patient Discharge Data for All-payer Patients 18+ Admitted to California Hospitals

Description	Total	FFS 65+	Non-FFS 65+	Age 18-64 Years
	# (%)	# (%)	# (%)	# (%)
All	45,480 (100)	18,647 (100)	11,014 (100)	15,819 (100)
Demographics				
Age	69 (13)	77 (8)	77 (7)	55 (8)
Cardiovascular/Respiratory				
History of Mechanical Ventilation (ICD-9 codes: 93.90, 96.70, 96.71, 96.72)	5,189 (11)	1,687 (9)	1,079 (10)	2,423 (15)
Sleep Apnea (ICD-9 codes: 327.20, 327.21, 327.23, 327.27, 327.29, 780.51, 780.53, 780.57)	4,149 (9)	1,187 (6)	662 (6)	2,300 (15)
Respirator Dependence/Respiratory Arrest (CC 77-78)	420 (1)	136 (1)	81 (1)	203 (1)
Cardio-Respiratory Failure and Shock (CC 79)	8,045 (18)	3,124 (17)	1,682 (15)	3,239 (20)
Congestive Heart Failure (CC 80)	11,428 (25)	5,205 (28)	2,709 (25)	3,514 (22)
Acute Coronary Syndrome (CC 81-82)	2,179 (5)	984 (5)	563 (5)	632 (4)
Chronic Atherosclerosis (CC 83-84)	14,991 (33)	7,468 (40)	3,885 (35)	3,638 (23)
Arrhythmias (CC 92-93)	8,483 (19)	4,147 (22)	2,325 (21)	2,011 (12.71)
Other and Unspecified Heart Disease (CC 94)	2,057 (4.52)	959 (5.14)	515 (4.68)	583 (3.69)
Vascular or Circulatory Disease (CC 104-106)	5,978 (13.14)	2,733 (14.66)	1,491 (13.54)	1,754 (11.09)
Fibrosis of Lung and Other Chronic Lung Disorder (CC 109)	3,271 (7.19)	1,624 (8.71)	786 (7.14)	861 (5.44)
Pneumonia (CC 111-113)	14,639 (32.19)	6,236 (33.44)	3,503 (31.80)	4,900 (30.98)
Comorbidities				
History of Infection (CC 1, 3-6)	6,389 (14.05)	2,721 (14.59)	1,217 (11.05)	2,451 (15.49)
Metastatic Cancer and Acute Leukemia (CC 7)	670 (1.47)	333 (1.79)	172 (1.56)	165 (1.04)
Lung, Upper Digestive Tract, and Other Severe Cancers (CC 8)	1,069 (2.35)	543 (2.91)	300 (2.72)	226 (1.43)
Lymphatic, Head and Neck, Brain, and Other Major Cancers; Breast, Colorectal and other Cancers and Tumors; Other Respiratory and Heart Neoplasms (CC 9-11)	1,797 (3.95)	909 (4.87)	516 (4.68)	372 (2.35)
Other Digestive and Urinary Neoplasms (CC 12)	760 (1.67)	395 (2.12)	154 (1.40)	211 (1.33)
Diabetes and DM Complications (CC 15-20, 119-120)	14,273 (31.38)	5,953 (31.92)	3,184 (28.91)	5,136 (32.47)
Protein-Calorie Malnutrition (CC 21)	2,869 (6.31)	1,348 (7.23)	742 (6.74)	779 (4.92)
Disorders of Fluid/Electrolyte/Acid-Base (CC 22-23)	11,369 (25.00)	4,864 (26.08)	2,392 (21.72)	4,113 (26.00)
Other Endocrine/Metabolic/Nutritional Disorders (CC 24)	23,679 (52.06)	9,753 (52.30)	5,916 (53.71)	8,010 (50.64)
Pancreatic Disease (CC 32)	2,885 (6.34)	975 (5.23)	685 (6.22)	1,225 (7.74)

Description	Total	FFS 65+	Non-FFS 65+	Age 18-64 Years
	# (%)	# (%)	# (%)	# (%)
Peptic Ulcer, Hemorrhage, Other Specified Gastrointestinal Disorders (CC 34)	3,299 (7.25)	1,471 (7.89)	761 (6.91)	1,067 (6.75)
Other Gastrointestinal Disorders (CC 36)	17,832 (39.21)	7,809 (41.88)	4,059 (36.85)	5,964 (37.70)
Severe Hematological Disorders (CC 44)	433 (0.95)	193 (1.04)	74 (0.67)	166 (1.05)
Iron Deficiency and Other/Unspecified Anemia and Blood Disease (CC 47)	14,660 (32.23)	6,673 (35.79)	3,575 (32.46)	4,412 (27.89)
Dementia or Senility (CC 49-50)	3,967 (8.72)	2,551 (13.68)	1,132 (10.28)	284 (1.80)
Drug/Alcohol Induced Dependence/Psychosis (CC 51-52)	3,633 (7.99)	819 (4.39)	522 (4.74)	2,292 (14.49)
Major Psychiatric Disorders (CC 54-56)	4,575 (10.06)	1,267 (6.79)	466 (4.23)	2,842 (17.97)
Depression (CC 58)	8,933 (19.64)	3,286 (17.62)	1,724 (15.65)	3,923 (24.80)
Anxiety Disorders (CC 59)	920 (2.02)	289 (1.55)	145 (1.32)	486 (3.07)
Other Psychiatric Disorders (CC 60)	6,800 (14.95)	2,469 (13.24)	1,469 (13.34)	2,862 (18.09)
Quadriplegia, Paraplegia, Functional Disability (CC 67-69, 100-102, 177-178)	1,533 (3.37)	684 (3.67)	341 (3.10)	508 (3.21)
Polyneuropathy (CC 71)	2,540 (5.58)	942 (5.05)	666 (6.05)	932 (5.89)
Hypertensive Heart and Renal Disease or Encephalopathy (CC 89)	884 (1.94)	417 (2.24)	314 (2.85)	153 (0.97)
Stroke (CC 95-96)	544 (1.20)	269 (1.44)	130 (1.18)	145 (0.92)
Renal Failure (CC 131)	4,325 (9.51)	2,026 (10.87)	1,194 (10.84)	1,105 (6.99)
Decubitus Ulcer or Chronic Skin Ulcer (CC 148-149)	1,576 (3.47)	692 (3.71)	336 (3.05)	548 (3.46)
Cellulitis, Local Skin Infection (CC 152)	2,177 (4.79)	706 (3.79)	326 (2.96)	1,145 (7.24)
Vertebral Fractures (CC 157)	1,102 (2.42)	589 (3.16)	267 (2.42)	246 (1.56)
Outcome				
Readmission within one month of discharge	9,344 (20.55)	3,869 (20.75)	2,193 (19.91)	3,282 (20.75)

Note:

1. FFS is defined as payer category=Medicare and payer type of coverage=Traditional.
2. The distribution for all risk factors is significantly different (at the p=0.05 level) across subgroups

Table 6a. Odds Ratios for Risk Factors in COPD Mortality Measure for All Patients 18+ Years (Logistic Regression Model, N=39,232 C-Statistic=0.744)

Data Source: 2006 California Patient Discharge Data for All-payer Patients 18+ Admitted to California Hospitals

Description	OR (95% CI)
Demographics	
Age	1.04 (1.04-1.05)
Cardiovascular/Respiratory	
History of Mechanical Ventilation (ICD-9 codes: 93.90, 96.70, 96.71, 96.72)	1.28 (1.10-1.48)
Sleep Apnea (ICD-9 codes: 327.20, 327.21, 327.23, 327.27, 327.29, 780.51, 780.53, 780.57)	1.06 (0.91-1.24)
Respirator Dependence/Respiratory Arrest (CC 77-78)	0.54 (0.37-0.81)
Cardio-Respiratory Failure and Shock (CC 79)	1.23 (1.09-1.39)
Congestive Heart Failure (CC 80)	1.25 (1.12-1.38)
Chronic Atherosclerosis (CC 83-84)	0.97 (0.89-1.06)
Arrhythmias (CC 92-93)	1.16 (1.05-1.28)
Vascular or Circulatory Disease (CC 104-106)	0.98 (0.88-1.10)
Fibrosis of Lung and Other Chronic Lung Disorder (CC 109)	1.27 (1.12-1.44)
Asthma (CC 110)	0.53 (0.42-0.66)
Pneumonia (CC 111-113)	1.64 (1.50-1.78)
Pleural Effusion/Pneumothorax (CC 114)	1.19 (0.99-1.45)
Other Lung Disorders (CC 115)	0.80 (0.72-0.90)
Comorbidities	
Metastatic Cancer and Acute Leukemia (CC 7)	2.33 (1.88-2.89)
Lung, Upper Digestive Tract, and Other Severe Cancers (CC 8)	2.33 (1.96-2.78)
Lymphatic, Head and Neck, Brain, and Other Major Cancers; Breast, Colorectal and other Cancers and Tumors; Other Respiratory and Heart Neoplasms (CC 9-11)	1.40 (1.20-1.64)
Other Digestive and Urinary Neoplasms (CC 12)	0.83 (0.63-1.11)
Diabetes and DM Complications (CC 15-20, 119-120)	1.01 (0.92-1.10)
Protein-Calorie Malnutrition (CC 21)	2.08 (1.86-2.33)
Disorders of Fluid/Electrolyte/Acid-Base (CC 22-23)	1.09 (0.99-1.21)
Other Endocrine/Metabolic/Nutritional Disorders (CC 24)	0.85 (0.78-0.92)
Other Gastrointestinal Disorders (CC 36)	0.86 (0.79-0.93)
Osteoarthritis of Hip or Knee (CC 40)	0.73 (0.56-0.97)
Other Musculoskeletal and Connective Tissue Disorders (CC 43)	0.85 (0.78-0.92)
Iron Deficiency and Other/Unspecified Anemia and Blood Disease (CC 47)	1.23 (1.13-1.33)
Dementia or Senility (CC 49-50)	1.16 (1.04-1.29)
Drug/Alcohol Abuse, without Dependence (CC 53)	0.95 (0.86-1.04)
Other Psychiatric Disorders (CC 60)	1.22 (1.09-1.36)
Quadriplegia, Paraplegia, Functional Disability (CC 67-69, 100-102, 177-178)	1.04 (0.86-1.26)
Mononeuropathy, Other Neurological Conditions/Injuries (CC 76)	0.87 (0.73-1.04)
Hypertension and Hypertensive Disease (CC 90-91)	0.85 (0.78-0.92)

Description	OR (95% CI)
Stroke (CC 95-96)	1.19 (0.89-1.61)
Retinal Disorders, except Detachment and Vascular Retinopathies (CC 121)	0.88 (0.64-1.21)
Other Eye Disorders (CC 124)	1.23 (0.98-1.55)
Other Ear, Nose, Throat, and Mouth Disorders (CC 127)	0.78 (0.67-0.90)
Renal Failure (CC 131)	0.90 (0.79-1.02)
Decubitus Ulcer or Chronic Skin Ulcer (CC 148-149)	1.43 (1.21-1.69)
Other Dermatological Disorders (CC 153)	0.92 (0.76-1.12)
Trauma (CC 154-156, 158-161)	1.33 (1.09-1.61)
Vertebral Fractures (CC 157)	1.25 (1.02-1.54)
Major Complications of Medical Care and Trauma (CC 164)	0.79 (0.63-0.98)

Table 6b. Odds Ratios for Risk Factors in COPD Readmission Measure for All Patients 18+ Years (Logistic Regression Model, N=45,480, C-Statistic=0.669)

Data Source: 2006 California Patient Discharge Data for All-payer Patients 18+ Admitted to California Hospitals

Description	OR (95% CI)
Demographics	
Age	1.00 (1.00-1.00)
Cardiovascular/Respiratory	
History of Mechanical Ventilation (ICD-9 codes: 93.90, 96.70, 96.71, 96.72)	1.12 (1.03-1.22)
Sleep Apnea (ICD-9 codes: 327.20, 327.21, 327.23, 327.27, 327.29, 780.51, 780.53, 780.57)	1.02 (0.94-1.11)
Respirator Dependence/Respiratory Arrest (CC 77-78)	1.08 (0.87-1.33)
Cardio-Respiratory Failure and Shock (CC 79)	1.18 (1.10-1.28)
Congestive Heart Failure (CC 80)	1.25 (1.17-1.33)
Acute Coronary Syndrome (CC 81-82)	1.02 (0.92-1.13)
Chronic Atherosclerosis (CC 83-84)	1.17 (1.11-1.23)
Arrhythmias (CC 92-93)	1.18 (1.11-1.25)
Other and Unspecified Heart Disease (CC 94)	1.09 (0.98-1.21)
Vascular or Circulatory Disease (CC 104-106)	1.10 (1.03-1.18)
Fibrosis of Lung and Other Chronic Lung Disorder (CC 109)	1.02 (0.94-1.12)
Pneumonia (CC 111-113)	1.18 (1.11-1.24)
Comorbidities	
History of Infection (CC 1, 3-6)	1.23 (1.16-1.33)
Metastatic Cancer and Acute Leukemia (CC 7)	1.24 (1.02-1.50)
Lung, Upper Digestive Tract, and Other Severe Cancers (CC 8)	1.29 (1.04-1.42)
Lymphatic, Head and Neck, Brain, and Other Major Cancers; Breast, Colorectal and other Cancers and Tumors; Other Respiratory and Heart Neoplasms (CC 9-11)	1.12 (1.00-1.26)
Other Digestive and Urinary Neoplasms (CC 12)	1.04 (0.88-1.23)
Diabetes and DM Complications (CC 15-20, 119-120)	1.13 (1.07-1.19)
Protein-Calorie Malnutrition (CC 21)	1.07 (0.97-1.17)
Disorders of Fluid/Electrolyte/Acid-Base (CC 22-23)	1.19 (1.12-1.26)
Other Endocrine/Metabolic/Nutritional Disorders (CC 24)	0.93 (0.89-0.98)
Pancreatic Disease (CC 32)	1.09 (1.00-1.19)
Peptic Ulcer, Hemorrhage, Other Specified Gastrointestinal Disorders (CC 34)	1.07 (0.98-1.16)
Other Gastrointestinal Disorders (CC 36)	1.14 (1.08-1.20)
Severe Hematological Disorders (CC 44)	1.48 (1.21-1.83)
Iron Deficiency and Other/Unspecified Anemia and Blood Disease (CC 47)	1.25 (1.19-1.32)
Dementia or Senility (CC 49-50)	1.02 (0.93-1.10)
Drug/Alcohol Induced Dependence/Psychosis (CC 51-52)	1.33 (1.23-1.45)
Major Psychiatric Disorders (CC 54-56)	1.34 (1.25-1.45)
Depression (CC 58)	1.04 (0.98-1.10)
Anxiety Disorders (CC 59)	1.24 (1.07-1.44)

Description	OR (95% CI)
Other Psychiatric Disorders (CC 60)	1.20 (1.12-1.27)
Quadriplegia, Paraplegia, Functional Disability (CC 67-69, 100-102, 177-178)	1.07 (0.95-1.21)
Polyneuropathy (CC 71)	1.06 (0.96-1.16)
Hypertensive Heart and Renal Disease or Encephalopathy (CC 89)	1.17 (1.00-1.37)
Stroke (CC 95-96)	0.89 (0.72-1.09)
Renal Failure (CC 131)	1.09 (1.01-1.19)
Decubitus Ulcer or Chronic Skin Ulcer (CC 148-149)	1.09 (0.97-1.23)
Cellulitis, Local Skin Infection (CC 152)	1.23 (1.11-1.36)
Vertebral Fractures (CC 157)	1.38 (1.20-1.58)

Table 7a. COPD Mortality Model Performance for Models with All 18+ Patients and by Subgroups of Patients

Data Source: 2006 California Patient Discharge Data for All-payer Patients 18+ Admitted to California Hospitals

Model with*	N	Unadjusted Readmission Rate (%)	C-statistic	SE	Lower C-stat	Upper C-stat	Predictive ability#, % (lowest decile – highest decile)
All 65+	26,546	2,805 (11)	0.702	0.005	0.692	0.712	(3.97%, 25.31%)
FFS, 65+	16,629	1,621 (10)	0.704	0.007	0.691	0.717	(4.00%, 23.02%)
Non-FFS, 65+	9,917	1,184 (12)	0.702	0.008	0.686	0.717	(3.92%, 29.90%)
All 18-64	12,686	424 (3)	0.735	0.013	0.711	0.760	(1.01%, 22.11%)
All 18+ (overall)	39,232	3,229 (8)	0.744	0.004	0.736	0.753	(1.12%, 25.16%)

*Note that a single overall model for all 18+ is applied to the subgroups of patients.

Table 7b. COPD Readmission Model Performance for Models with All 18+ Patients and by Subgroups of Patients

Data Source: 2006 California Patient Discharge Data for All-payer Patients 18+ Admitted to California Hospitals

Model with*	N	Unadjusted Readmission Rate (%)	C-statistic	SE	Lower C-stat	Upper C-stat	Predictive ability[#], % (lowest decile – highest decile)
All 65+	29,661	6,062(20.44)	0.643	0.004	0.635	0.651	(10.28%, 38.29%)
FFS, 65+	18,647	3,869 (20.75)	0.640	0.005	0.631	0.650	(10.34%, 37.68%)
Non-FFS, 65+	11,014	2,193 (19.91)	0.647	0.007	0.634	0.660	(10.21%, 39.60%)
All 18-64	15,819	3,282 (20.75)	0.715	0.005	0.704	0.725	(8.45%, 50.23%)
All 18+ (overall)	45,480	9,344 (20.55)	0.669	0.003	0.663	0.675	(9.43%, 42.92%)

*Note that a single overall model for all 18+ is applied to the subgroups of patients.

Table 8a. Distribution of Pearson Chi-Square Residuals for COPD Mortality Model by Patient Subgroups

Data Source: 2006 California Patient Discharge Data for All-payer Patients 18+ Admitted to California Hospitals

	All 18+ (TOTAL)	All 65+	FFS 65+	Non-FFS 65+	All 18-64
N	39,232	26,546	16,629	9,917	12,686
Mean	0.00	0.01	-0.03	0.06	-0.03
Std Deviation	0.97	1.01	0.96	1.08	0.90
100% Max	12.26	7.59	7.11	7.59	12.26
99%	4.38	4.13	4.04	4.25	5.38
95%	2.48	2.75	2.58	2.98	-0.08
90%	-0.10	1.29	-0.13	1.78	-0.11
75% Q3	-0.17	-0.22	-0.22	-0.21	-0.14
50% Median	-0.24	-0.27	-0.28	-0.27	-0.17
25% Q1	-0.31	-0.35	-0.35	-0.34	-0.20
10%	-0.41	-0.45	-0.46	-0.43	-0.26
5%	-0.49	-0.54	-0.55	-0.52	-0.31
1%	-0.73	-0.79	-0.80	-0.76	-0.46
0% Min	-1.87	-1.87	-1.85	-1.87	-1.09

Residual < -2	0 (0.00%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	0 (0.00%)
-2 <= Residual < 0	36,003 (91.77%)	23,741 (89.43%)	15,008 (90.25%)	8,733 (88.06%)	12,262 (96.66%)
0 <= Residual < 2	709 (1.81%)	679 (2.56%)	411 (2.47%)	268 (2.70%)	30 (0.24%)
Residual >= 2	2,520 (6.42%)	2,126 (8.01%)	1,210 (7.28%)	916 (9.24%)	394 (3.11%)

Table 8b. Distribution of Pearson Chi-Square Residuals for COPD Readmission Model by Patient Subgroups

Data Source: 2006 California Patient Discharge Data for All-payer Patients 18+ Admitted to California Hospitals

	All 18+ (TOTAL)	All 65+	FFS 65+	Non-FFS 65+	All 18-64
N	45,480	29,661	18,647	11,014	15,819
Mean	0.00	0.00	0.00	0.01	-0.01
Std Deviation	1.00	1.01	1.01	1.01	0.97
100% Max	3.07	3.07	3.07	2.89	2.90
99%	2.79	2.78	2.78	2.79	2.79
95%	2.35	2.38	2.38	2.40	2.26
90%	1.90	1.96	1.95	2.00	1.77
75% Q3	-0.36	-0.36	-0.36	-0.36	-0.36
50% Median	-0.40	-0.41	-0.41	-0.40	-0.40
25% Q1	-0.50	-0.51	-0.51	-0.49	-0.50
10%	-0.65	-0.65	-0.66	-0.63	-0.64
5%	-0.76	-0.76	-0.78	-0.73	-0.76
1%	-1.01	-0.99	-1.01	-0.98	-1.04
0% Min	-2.16	-1.87	-1.87	-1.69	-2.16

Residual < -2	1 (0.00%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	1 (0.00%)
-2 <= Residual < 0	36,135 (79.45%)	23,599 (79.56%)	14,778 (79.25%)	8,821 (80.09%)	12,536 (79.25%)
0 <= Residual < 2	5,287 (11.62%)	3,213 (10.83%)	2,116 (11.35%)	1,097 (9.96%)	2,074 (13.11%)
Residual >= 2	4,057 (8.92%)	2,849 (9.61%)	1,753 (9.40%)	1,096 (9.95%)	1,208 (7.64%)

Table 9a. Odds Ratios for Risk Factors in COPD Mortality Measure -- Stratified Results for FFS Patients 65+, Non-FFS Patients 65+, All Patients 65+, and All Patients 18-64 Years of Age

Data Source: 2006 California Patient Discharge Data for All-payer Patients 18+ Admitted to California Hospitals

Risk Factor	OR (95% CI) for All 65+ (N=26,546, C-statistic=0.703)	OR (95% CI) for FFS 65+ (N=16,629, C-Statistic=0.706)	OR (95% CI) for Non-FFS 65+ (N=9,917, C-Statistic=0.710)	OR (95% CI) for All 18-64 (N=12,686, C-Statistic=0.757)
Demographics				
Age	1.03 (1.03-1.04)	1.04 (1.03-1.05)	1.03 (1.02-1.04)	1.03 (1.01-1.05)
Cardiovascular/Respiratory				
History of Mechanical Ventilation (ICD-9 codes: 93.90, 96.70, 96.71, 96.72)	1.29 (1.10-1.52)	1.43 (1.16-1.77)	1.06 (0.82-1.37	1.13 (0.81-1.58)
Sleep Apnea (ICD-9 codes: 327.20, 327.21, 327.23, 327.27, 327.29, 780.51, 780.53, 780.57)	1.00 (0.83-1.20)	1.00 (0.78-1.27)	1.00 (0.74-1.35)	1.17 (0.86-1.58)
Respirator Dependence/Respiratory Arrest (CC 77-78)	0.51 (0.32-0.81)	0.64 (0.37-1.12)	0.34 (0.15-0.76)	0.66 (0.31-1.44)
Cardio-Respiratory Failure and Shock (CC 79)	1.16 (1.02-1.33)	1.13 (0.95-1.35)	1.25 (1.01-1.56)	1.63 (1.19-2.23)
Congestive Heart Failure (CC 80)	1.23 (1.10-1.37)	1.19 (1.03-1.38)	1.35 (1.13-1.61)	1.41 (1.07-1.87)
Chronic Atherosclerosis (CC 83-84)	0.97 (0.88-1.06)	1.01 (0.90-1.14)	0.95 (0.82-1.09)	1.00 (0.78-1.28)
Arrhythmias (CC 92-93)	1.17 (1.05-1.30)	1.11 (0.97-1.28)	1.24 (1.04-1.47)	1.16 (0.87-1.55)
Vascular or Circulatory Disease (CC 104-106)	0.96 (0.85-1.08)	0.97 (0.83-1.14)	0.93 (0.76-1.13)	1.17 (0.86-1.58)
Fibrosis of Lung and Other Chronic Lung Disorder (CC 109)	1.18 (1.03-1.35)	1.15 (0.97-1.37)	1.25 (1.01-1.56)	2.07 (1.50-2.84)
Asthma (CC 110)	0.54 (0.42-0.70)	0.52 (0.37-0.72)	0.59 (0.40-0.89)	0.49 (0.31-0.76)
Pneumonia (CC 111-113)	1.66 (1.51-1.81)	1.77 (1.57-1.99)	1.52 (1.32-1.75)	1.50 (1.19-1.89)
Pleural Effusion/Pneumothorax (CC 114)	1.21 (0.98-1.49)	1.13 (0.86-1.48)	1.28 (0.93-1.78)	1.12 (0.69-1.84)
Other Lung Disorders (CC 115)	0.82 (0.74-0.92)	0.82 (0.71-0.95)	0.86 (0.72-1.04)	0.71 (0.54-0.94)
Comorbidities				
Metastatic Cancer and Acute Leukemia (CC 7)	2.12 (1.67-2.67)	2.41 (1.80-3.22)	1.78 (1.20-2.64)	3.59 (2.04-6.32)
Lung, Upper Digestive Tract, and Other Severe Cancers (CC 8)	2.25 (1.87-2.72)	2.09 (1.64-2.67)	2.57 (1.91-3.46)	2.40 (1.44-3.98)
Lymphatic, Head and Neck, Brain, and Other Major Cancers; Breast, Colorectal and other Cancers and Tumors; Other Respiratory and Heart Neoplasms (CC 9-11)	1.41 (1.19-1.66)	1.35 (1.09-1.67)	1.49 (1.14-1.93)	1.14 (0.87-2.28)
Other Digestive and Urinary Neoplasms (CC 12)	0.85 (0.62-1.14)	0.81 (0.55-1.18)	1.03 (0.62-1.70)	0.83 (0.35-1.95)
Diabetes and DM Complications (CC 15-20, 119-120)	1.00 (0.91-1.10)	0.97 (0.86-1.10)	1.07 (0.93-1.25)	0.98 (0.78-1.25)
Protein-Calorie Malnutrition (CC 21)	2.09 (1.85-2.36)	2.07 (1.76-2.42)	2.13 1.75-2.60)	1.95 (1.42-2.70)
Disorders of Fluid/Electrolyte/Acid-Base (CC 22-23)	1.08 (0.98-1.21)	1.05 (0.91-1.21)	1.16 (0.98-1.37)	1.15 (0.88-1.49)
Other Endocrine/Metabolic/Nutritional Disorders	0.83 (0.76-0.90)	0.89 (0.79-1.00)	0.72 (0.63-0.83)	0.98 (0.78-1.24)

Risk Factor	OR (95% CI) for All 65+ (N=26,546, C-statistic=0.703)	OR (95% CI) for FFS 65+ (N=16,629, C-Statistic=0.706)	OR (95% CI) for Non-FFS 65+ (N=9,917, C-Statistic=0.710)	OR (95% CI) for All 18-64 (N=12,686, C-Statistic=0.757)
(CC 24)				
Other Gastrointestinal Disorders (CC 36)	0.86 (0.78-0.94)	0.86 (0.76-0.96)	0.88 (0.77-1.02)	0.89 (0.71-1.12)
Osteoarthritis of Hip or Knee (CC 40)	0.73 (0.54-0.98)	0.80 (0.56-1.15)	0.60 (0.36-1.02)	0.78 (0.36-1.72)
Other Musculoskeletal and Connective Tissue Disorders (CC 43)	0.84 (0.77-0.92)	0.83 (0.73-0.93)	0.88 (0.76-1.02)	0.90 (0.71-1.13)
Iron Deficiency and Other/Unspecified Anemia and Blood Disease (CC 47)	1.21 (1.11-1.33)	1.24 (1.10-1.40)	1.18 (1.03-1.37)	1.30 (1.03-1.64)
Dementia or Senility (CC 49-50)	1.20 (1.07-1.34)	1.17 (1.0-1.35)	1.29 (1.07-1.54)	0.90 (0.48-1.71)
Drug/Alcohol Abuse, without Dependence (CC 53)	0.95 (0.86-1.06)	1.00 (0.88-1.15)	0.89 (0.77-1.05)	0.94 (0.76-1.16)
Other Psychiatric Disorders (CC 60)	1.22 (1.08-1.38)	1.05 (0.98-1.36)	1.30 (1.08-1.56)	1.14 (0.88-1.49)
Quadriplegia, Paraplegia, Functional Disability (CC 67-69, 100-102, 177-178)	0.96 (0.77-1.19)	0.87 (0.66-1.15)	1.13 (0.80-1.59)	1.59 (1.02-2.48)
Mononeuropathy, Other Neurological Conditions/Injuries (CC 76)	0.90 (0.74-1.09)	0.83 (0.64-1.07)	0.99 (0.73-1.33)	0.66 (0.41-1.05)
Hypertension and Hypertensive Disease (CC 90-91)	0.85 (0.78-0.93)	0.85 (0.76-0.96)	0.82 (0.72-0.94)	0.78 (0.62-0.97)
Stroke (CC 95-96)	1.05 (0.75-1.46)	0.93 (0.60-1.44)	1.27 (0.76-2.12)	2.70 (1.40-5.22)
Retinal Disorders, except Detachment and Vascular Retinopathies (CC 121)	0.90 (0.65-1.23)	0.88 (0.57-1.36)	0.86 (0.54-1.38)	1.43 (0.17-12.38)
Other Eye Disorders (CC 124)	1.13 (0.88-1.46)	0.97 (0.69-1.38)	1.32 (0.91-1.93)	1.80 (1.09-2.97)
Other Ear, Nose, Throat, and Mouth Disorders (CC 127)	0.76 (0.64-0.90)	0.81 (0.65-1.00)	0.69 (0.53-0.91)	0.86 (0.60-1.23)
Renal Failure (CC 131)	0.92 (0.81-1.06)	0.94 (0.79-1.13)	0.86 (0.69-1.06)	0.82 (0.56-1.19)
Decubitus Ulcer or Chronic Skin Ulcer (CC 148-149)	1.44 (1.20-1.73)	1.33 (1.04-1.69)	1.61 (1.19-2.16)	1.32 (0.87-1.99)
Other Dermatological Disorders (CC 153)	0.89 (0.72-1.12)	0.86 (0.64-1.15)	0.99 (0.69-1.40)	0.95 (0.63-1.45)
Trauma (CC 154-156, 158-161)	1.34 (1.09-1.65)	1.20 (0.91-1.58)	1.57 (1.14-2.16)	1.29 (0.75-2.24)
Vertebral Fractures (CC 157)	1.28 (1.02-1.58)	1.08 (0.82-1.44)	1.70 (1.21-2.40)	0.99 (0.47-2.07)
Major Complications of Medical Care and Trauma (CC 164)	0.82 (0.64-1.05)	0.92 (0.68-1.25)	0.63 (0.42-0.97)	0.59 (0.33-1.04)

Table 9b. Odds Ratios for Risk Factors in COPD Readmission Measure -- Stratified Results for FFS Patients 65+, Non-FFS Patients 65+, All Patients 65+, and All Patients 18-64 Years of Age

Data Source: 2006 California Patient Discharge Data for All-payer Patients 18+ Admitted to California Hospitals

Risk Factor	OR (95% CI) for All 65+ (N=54,773, C-statistic=0.617)	OR (95% CI) for FFS 65+ (N=33,784, C-Statistic=0.619)	OR (95% CI) for Non-FFS 65+ (N=20,989, C-Statistic=0.617)	OR (95% CI) for All 18-64 (N=21,763, C-Statistic=0.689)
Demographics				
Age	1.00 (0.99-1.00)	1.00 (0.99-1.00)	1.00 (0.99-1.01)	1.00 (0.99-1.00)
Cardiovascular/Respiratory				
History of Mechanical Ventilation (ICD-9 codes: 93.90, 96.70, 96.71, 96.72)	1.08 (0.96-1.20)	1.15 (1.00-1.32)	0.95 (0.79-1.14)	1.14 (0.99-1.31)
Sleep Apnea (ICD-9 codes: 327.20, 327.21, 327.23, 327.27, 327.29, 780.51, 780.53, 780.57)	1.07 (0.96-1.21)	1.10 (0.95-1.27)	1.06 (0.87-1.29)	0.94 (0.83-1.06)
Respirator Dependence/Respiratory Arrest (CC 77-78)	1.19 (0.89-1.59)	0.88 (0.60-1.28)	1.93 (1.21-3.07)	0.91 (0.66-1.24)
Cardio-Respiratory Failure and Shock (CC 79)	1.19 (1.08-1.31)	1.16 (1.03-1.30)	1.27 (1.08-1.49)	1.20 (1.06-1.37)
Congestive Heart Failure (CC 80)	1.20 (1.11-1.30)	1.18 (1.07-1.29)	1.26 (1.11-1.44)	1.37 (1.23-1.53)
Acute Coronary Syndrome (CC 81-82)	0.93 (0.82-1.06)	0.95 (0.81-1.11)	0.90 (0.73-1.11)	1.30 (1.08-1.57)
Chronic Atherosclerosis (CC 83-84)	1.15 (1.08-1.23)	1.15 (1.06-1.25)	1.15 (1.04-1.29)	1.20 (1.08-1.33)
Arrhythmias (CC 92-93)	1.22 (1.13-1.32)	1.18 (1.08-1.30)	1.31 (1.16-1.49)	1.13 (1.00-1.27)
Other and Unspecified Heart Disease (CC 94)	1.04 (0.92-1.18)	1.11 (0.95-1.29)	0.92 (0.74-1.14)	1.23 (1.01-1.49)
Vascular or Circulatory Disease (CC 104-106)	1.08 (0.99-1.17)	1.04 (0.93-1.15)	1.16 (1.01-1.34)	1.16 (1.02-1.32)
Fibrosis of Lung and Other Chronic Lung Disorder (CC 109)	1.00 (0.91-1.11)	0.95 (0.84-1.08)	1.14 (0.96-1.36)	1.08 (0.91-1.27)
Pneumonia (CC 111-113)	1.19 (1.11-1.27)	1.22 (1.13-1.33)	1.13 (1.01-1.26)	1.14 (1.04-1.25)
Comorbidities				
History of Infection (CC 1, 3-6)	1.14 (1.05-1.25)	1.11 (1.00-1.23)	1.23 (1.05-1.42)	1.40 (1.25-1.57)
Metastatic Cancer and Acute Leukemia (CC 7)	1.23 (0.98-1.54)	1.23 (0.93-1.62)	1.23 (0.83-1.82)	1.18 (0.78-1.79)
Lung, Upper Digestive Tract, and Other Severe Cancers (CC 8)	1.13 (0.95-1.35)	1.16 (0.94-1.44)	1.06 (0.78-1.43)	1.62 (1.16-2.28)
Lymphatic, Head and Neck, Brain, and Other Major Cancers; Breast, Colorectal and other Cancers and Tumors; Other Respiratory and Heart Neoplasms (CC 9-11)	1.15 (1.01-1.31)	1.09 (0.93-1.29)	1.27 (1.02-1.57)	1.05 (0.81-1.36)
Other Digestive and Urinary Neoplasms (CC 12)	1.05 (0.86-1.28)	1.05 (0.83-1.32)	1.05 (0.73-1.52)	1.10 (0.81-1.49)
Diabetes and DM Complications (CC 15-20, 119-120)	1.15 (1.07-1.22)	1.19 (1.10-1.29)	1.07 (0.96-1.19)	1.07 (0.97-1.18)
Protein-Calorie Malnutrition (CC 21)	1.09 (0.98-1.22)	1.19 (1.04-1.36)	0.92 (0.76-1.11)	1.03 (0.87-1.23)
Disorders of Fluid/Electrolyte/Acid-Base (CC 22-23)	1.11 (1.03-1.20)	1.08 (0.99-1.19)	1.17 (1.03-1.33)	1.31 (1.18-1.45)
Other Endocrine/Metabolic/Nutritional Disorders	0.93 (0.87-0.99)	0.91 (0.84-0.98)	0.97 (0.87-1.07)	0.93 (0.85-1.03)

Risk Factor	OR (95% CI) for All 65+ (N=54,773, C-statistic=0.617)	OR (95% CI) for FFS 65+ (N=33,784, C-Statistic=0.619)	OR (95% CI) for Non-FFS 65+ (N=20,989, C-Statistic=0.617)	OR (95% CI) for All 18-64 (N=21,763, C-Statistic=0.689)
(CC 24)				
Pancreatic Disease (CC 32)	1.09 (0.97-1.23)	1.09 (0.93-1.27)	1.09 (0.90-1.31)	1.05 (0.91-1.21)
Peptic Ulcer, Hemorrhage, Other Specified Gastrointestinal Disorders (CC 34)	1.03 (0.93-1.15)	1.03 (0.90-1.17)	1.04 (0.87-1.25)	1.16 (1.00-1.34)
Other Gastrointestinal Disorders (CC 36)	1.13 (1.06-1.20)	1.12 (1.03-1.21)	1.13 (1.02-1.26)	1.16 (1.06-1.27)
Severe Hematological Disorders (CC 44)	1.32 (1.01-1.72)	1.17 (0.86-1.61)	1.88 (1.14-3.09)	1.75 (1.25-2.45)
Iron Deficiency and Other/Unspecified Anemia and Blood Disease (CC 47)	1.26 (1.18-1.34)	1.25 (1.15-1.36)	1.26 (1.13-1.40)	1.25 (1.14-1.37)
Dementia or Senility (CC 49-50)	1.07 (0.97-1.17)	1.11 (0.99-1.23)	0.97 (0.83-1.15)	0.98 (0.74-1.29)
Drug/Alcohol Induced Dependence/Psychosis (CC 51-52)	1.20 (1.05-1.36)	1.10 (0.93-1.30)	1.40 (1.14-1.71)	1.35 (1.21-1.51)
Major Psychiatric Disorders (CC 54-56)	1.15 (1.02-1.29)	1.16 (1.01-1.33)	1.16 (0.93-1.45)	1.48 (1.34-1.64)
Depression (CC 58)	0.96 (0.89-1.04)	0.98 (0.89-1.08)	0.93 (0.81-1.06)	1.16 (1.06-1.28)
Anxiety Disorders (CC 59)	1.16 (0.93-1.45)	1.13 (0.86-1.48)	1.26 (0.85-1.84)	1.26 (1.02-1.56)
Other Psychiatric Disorders (CC 60)	1.19 (1.09-1.29)	1.18 (1.06-1.31)	1.21 (1.05-1.38)	1.20 (1.08-1.33)
Quadriplegia, Paraplegia, Functional Disability (CC 67-69, 100-102, 177-178)	1.02 (0.87-1.19)	1.05 (0.87-1.26)	0.94 (0.72-1.23)	1.19 (0.96-1.47)
Polyneuropathy (CC 71)	1.12 (0.99-1.26)	1.14 (0.98-1.33)	1.07 (0.88-1.30)	0.95 (0.80-1.12)
Hypertensive Heart and Renal Disease or Encephalopathy (CC 89)	1.08 (0.91-1.29)	1.04 (0.83-1.31)	1.14 (0.87-1.49)	1.69 (1.19-2.40)
Stroke (CC 95-96)	0.95 (0.74-1.21)	0.89 (0.66-1.20)	1.08 (0.71-1.64)	0.75 (0.50-1.12)
Renal Failure (CC 131)	1.10 (1.00-1.21)	1.18 (1.05-1.33)	0.95 (0.81-1.12)	1.17 (1.01-1.37)
Decubitus Ulcer or Chronic Skin Ulcer (CC 148-149)	1.18 (1.02-1.37)	1.21 (1.01-1.45)	1.17 (0.90-1.51)	1.01 (0.82-1.23)
Cellulitis, Local Skin Infection (CC 152)	1.02 (0.88-1.18)	1.04 (0.86-1.24)	0.97 (0.75-1.27)	1.34 (1.16-1.56)
Vertebral Fractures (CC 157)	1.38 (1.18-1.60)	1.33 (1.10-1.60)	1.52 (1.15-1.99)	1.47 (1.11-1.95)

Table 10a. COPD Mortality Model with Interaction Terms – Logistic Regression Model (N=39,232, C-Statistic=0.746)

Data Source: 2006 California Patient Discharge Data for All-payer Patients 18+ Admitted to California Hospitals

Description	Estimate	Standard Error	Wald Chi-Square	P value	OR	LOR	UOR
Intercept	-5.633	0.200	796.383	0.000			
Demographics							
Age	0.033	0.003	138.394	0.000	1.03	1.03	1.04
Cardiovascular/Respiratory							
History of Mechanical Ventilation (ICD-9 codes: 93.90, 96.70, 96.71, 96.72)	0.127	0.169	0.564	0.453	1.14	0.82	1.58
Sleep Apnea (ICD-9 codes: 327.20, 327.21, 327.23, 327.27, 327.29, 780.51, 780.53, 780.57)	0.163	0.154	1.123	0.289	1.18	0.87	1.59
Respirator Dependence/Respiratory Arrest (CC 77-78)	-0.407	0.394	1.064	0.302	0.67	0.31	1.44
Cardio-Respiratory Failure and Shock (CC 79)	0.489	0.159	9.423	0.002	1.63	1.19	2.23
Congestive Heart Failure (CC 80)	0.345	0.142	5.897	0.015	1.41	1.07	1.86
Chronic Atherosclerosis (CC 83-84)	-0.008	0.128	0.004	0.951	0.99	0.77	1.27
Arrhythmias (CC 92-93)	0.146	0.148	0.966	0.326	1.16	0.87	1.55
Vascular or Circulatory Disease (CC 104-106)	0.152	0.155	0.966	0.326	1.16	0.86	1.58
Fibrosis of Lung and Other Chronic Lung Disorder (CC 109)	0.726	0.163	19.809	0.000	2.07	1.50	2.84
Asthma (CC 110)	-0.701	0.228	9.453	0.002	0.50	0.32	0.78
Pneumonia (CC 111-113)	0.404	0.118	11.776	0.001	1.50	1.19	1.89
Pleural Effusion/Pneumothorax (CC 114)	0.115	0.252	0.208	0.648	1.12	0.68	1.84
Other Lung Disorders (CC 115)	-0.336	0.143	5.504	0.019	0.71	0.54	0.95
Comorbidities							
Metastatic Cancer and Acute Leukemia (CC 7)	1.279	0.289	19.626	0.000	3.59	2.04	6.33
Lung, Upper Digestive Tract, and Other Severe Cancers (CC 8)	0.867	0.259	11.237	0.001	2.38	1.43	3.95
Lymphatic, Head and Neck, Brain, and Other Major Cancers; Breast, Colorectal and other Cancers and Tumors; Other	0.335	0.246	1.855	0.173	1.40	0.86	2.26

Description	Estimate	Standard Error	Wald Chi-Square	P value	OR	LOR	UOR
Respiratory and Heart Neoplasms (CC 9-11)							
Other Digestive and Urinary Neoplasms (CC 12)	-0.186	0.434	0.183	0.669	0.83	0.35	1.95
Diabetes and DM Complications (CC 15-20, 119-120)	-0.018	0.120	0.021	0.884	0.98	0.78	1.24
Protein-Calorie Malnutrition (CC 21)	0.666	0.164	16.511	0.000	1.95	1.41	2.68
Disorders of Fluid/Electrolyte/Acid-Base (CC 22-23)	0.138	0.134	1.067	0.302	1.15	0.88	1.49
Other Endocrine/Metabolic/Nutritional Disorders (CC 24)	-0.017	0.117	0.020	0.887	0.98	0.78	1.24
Other Gastrointestinal Disorders (CC 36)	-0.114	0.115	0.969	0.325	0.89	0.71	1.12
Osteoarthritis of Hip or Knee (CC 40)	-0.247	0.400	0.379	0.538	0.78	0.36	1.71
Other Musculoskeletal and Connective Tissue Disorders (CC 43)	-0.112	0.120	0.869	0.351	0.89	0.71	1.13
Iron Deficiency and Other/Unspecified Anemia and Blood Disease (CC 47)	0.261	0.119	4.793	0.029	1.30	1.03	1.64
Dementia or Senility (CC 49-50)	-0.108	0.324	0.111	0.739	0.90	0.48	1.69
Drug/Alcohol Abuse, without Dependence (CC 53)	-0.055	0.106	0.271	0.602	0.95	0.77	1.17
Other Psychiatric Disorders (CC 60)	0.131	0.135	0.944	0.331	1.14	0.88	1.49
Quadriplegia, Paraplegia, Functional Disability (CC 67-69, 100-102, 177-178)	0.464	0.227	4.177	0.041	1.59	1.02	2.48
Mononeuropathy, Other Neurological Conditions/Injuries (CC 76)	-0.415	0.237	3.075	0.080	0.66	0.41	1.05
Hypertension and Hypertensive Disease (CC 90-91)	-0.254	0.113	5.070	0.024	0.78	0.62	0.97
Stroke (CC 95-96)	0.990	0.336	8.675	0.003	2.69	1.39	5.20
Retinal Disorders, except Detachment and Vascular Retinopathies (CC 121)	0.351	1.101	0.101	0.750	1.42	0.16	12.28
Other Eye Disorders (CC 124)	0.592	0.256	5.360	0.021	1.81	1.10	2.99
Other Ear, Nose, Throat, and Mouth Disorders (CC 127)	-0.146	0.182	0.644	0.422	0.86	0.61	1.23
Renal Failure (CC 131)	-0.202	0.190	1.130	0.288	0.82	0.56	1.19
Decubitus Ulcer or Chronic Skin Ulcer (CC 148-149)	0.279	0.211	1.757	0.185	1.32	0.87	2.00
Other Dermatological Disorders (CC 153)	-0.045	0.214	0.045	0.833	0.96	0.63	1.45

Description	Estimate	Standard Error	Wald Chi-Square	P value	OR	LOR	UOR
Trauma (CC 154-156, 158-161)	0.256	0.280	0.836	0.361	1.29	0.75	2.23
Vertebral Fractures (CC 157)	-0.016	0.378	0.002	0.967	0.98	0.47	2.06
Major Complications of Medical Care and Trauma (CC 164)	-0.526	0.292	3.249	0.071	0.59	0.33	1.05
Older(Age>=65)	0.631	0.145	19.051	0.000	1.88	1.42	2.50
Interactions							
Cardiovascular/Respiratory							
Older and History of Mechanical Ventilation (ICD-9 codes: 93.90, 96.70, 96.71, 96.72)	0.129	0.188	0.473	0.492	1.14	0.79	1.65
Older and Sleep Apnea (ICD-9 codes: 327.20, 327.21, 327.23, 327.27, 327.29, 780.51, 780.53, 780.57)	-0.167	0.181	0.850	0.356	0.85	0.59	1.21
Older and Respirator Dependence/Respiratory Arrest (CC 77-78)	-0.267	0.459	0.338	0.561	0.77	0.31	1.88
Older and Cardio-Respiratory Failure and Shock (CC 79)	-0.338	0.174	3.775	0.052	0.71	0.51	1.00
Older and Congestive Heart Failure (CC 80)	-0.140	0.153	0.840	0.359	0.87	0.64	1.17
Older and Chronic Atherosclerosis (CC 83-84)	-0.024	0.136	0.032	0.857	0.98	0.75	1.27
Older and Arrhythmias (CC 92-93)	0.012	0.158	0.006	0.941	1.01	0.74	1.38
Older and Vascular or Circulatory Disease (CC 104-106)	-0.196	0.167	1.382	0.240	0.82	0.59	1.14
Older and Fibrosis of Lung and Other Chronic Lung Disorder (CC 109)	-0.558	0.177	9.917	0.002	0.57	0.40	0.81
Older and Asthma (CC 110)	0.089	0.263	0.115	0.734	1.09	0.65	1.83
Older and Pneumonia (CC 111-113)	0.100	0.126	0.626	0.429	1.11	0.86	1.42
Older and Pleural Effusion/Pneumothorax (CC 114)	0.076	0.273	0.078	0.780	1.08	0.63	1.84
Older and Other Lung Disorders (CC 115)	0.144	0.155	0.860	0.354	1.15	0.85	1.56
Comorbidities							
Older and Metastatic Cancer and Acute Leukemia (CC 7)	-0.530	0.312	2.884	0.089	0.59	0.32	1.09
Older and Lung, Upper Digestive Tract, and Other Severe Cancers (CC 8)	-0.055	0.276	0.040	0.841	0.95	0.55	1.62
Older and Lymphatic, Head and Neck, Brain, and Other Major	0.007	0.260	0.001	0.977	1.01	0.61	1.68

Description	Estimate	Standard Error	Wald Chi-Square	P value	OR	LOR	UOR
Cancers; Breast, Colorectal and other Cancers and Tumors; Other Respiratory and Heart Neoplasms (CC 9-11)							
Older and Other Digestive and Urinary Neoplasms (CC 12)	0.018	0.461	0.001	0.969	1.02	0.41	2.51
Older and Diabetes and DM Complications (CC 15-20, 119-120)	0.020	0.130	0.023	0.880	1.02	0.79	1.31
Older and Protein-Calorie Malnutrition (CC 21)	0.071	0.176	0.163	0.686	1.07	0.76	1.51
Older and Disorders of Fluid/Electrolyte/Acid-Base (CC 22-23)	-0.057	0.144	0.158	0.691	0.94	0.71	1.25
Older and Other Endocrine/Metabolic/Nutritional Disorders (CC 24)	-0.176	0.125	1.981	0.159	0.84	0.66	1.07
Older and Other Gastrointestinal Disorders (CC 36)	-0.040	0.124	0.103	0.748	0.96	0.75	1.23
Older and Osteoarthritis of Hip or Knee (CC 40)	-0.073	0.428	0.029	0.865	0.93	0.40	2.15
Older and Other Musculoskeletal and Connective Tissue Disorders (CC 43)	-0.061	0.129	0.221	0.638	0.94	0.73	1.21
Older and Iron Deficiency and Other/Unspecified Anemia and Blood Disease (CC 47)	-0.069	0.128	0.287	0.592	0.93	0.73	1.20
Older and Dementia or Senility (CC 49-50)	0.291	0.329	0.782	0.377	1.34	0.70	2.55
Older and Drug/Alcohol Abuse, without Dependence (CC 53)	0.007	0.118	0.003	0.955	1.01	0.80	1.27
Older and Other Psychiatric Disorders (CC 60)	0.068	0.148	0.210	0.647	1.07	0.80	1.43
Older and Hemiplegia, Paraplegia, Paralysis, Functional Disability (CC 67-69, 100-102, 177-178)	-0.506	0.252	4.021	0.045	0.60	0.37	0.99
Older and Mononeuropathy, Other Neurological Conditions/Injuries (CC 76)	0.309	0.257	1.445	0.229	1.36	0.82	2.25
Older and Hypertension and Hypertensive Disease (CC 90-91)	0.090	0.121	0.549	0.459	1.09	0.86	1.39
Older and Stroke (CC 95-96)	-0.943	0.376	6.289	0.012	0.39	0.19	0.81
Older and Retinal Disorders, except Detachment and Vascular Retinopathies (CC 121)	-0.458	1.113	0.169	0.681	0.63	0.07	5.60
Older and Other Eye Disorders (CC 124)	-0.469	0.287	2.679	0.102	0.63	0.36	1.10
Older and Other Ear, Nose, Throat, and Mouth Disorders (CC 127)	-0.127	0.201	0.400	0.527	0.88	0.59	1.31
Older and Renal Failure (CC 131)	0.122	0.202	0.364	0.546	1.13	0.76	1.68

Description	Estimate	Standard Error	Wald Chi-Square	P value	OR	LOR	UOR
Older and Decubitus Ulcer or Chronic Skin Ulcer (CC 148-149)	0.084	0.231	0.134	0.714	1.09	0.69	1.71
Older and Other Dermatological Disorders (CC 153)	-0.067	0.242	0.076	0.782	0.94	0.58	1.50
Older and Trauma (CC 154-156, 158-161)	0.039	0.299	0.017	0.896	1.04	0.58	1.87
Older and Vertebral Fractures (CC 157)	0.254	0.394	0.417	0.518	1.29	0.60	2.79
Older and Major Complications of Medical Care and Trauma (CC 164)	0.326	0.318	1.054	0.305	1.39	0.74	2.58

Table 10b. COPD Readmission Model with Interaction Terms – Logistic Regression Model (N=60,022, C-statistic= 0.720)

Data Source: 2006 California Patient Discharge Data for All-payer Patients 18+ Admitted to California Hospitals

Description	Estimate	Standard Error	Wald Chi-Square	P value	OR	LOR	UOR
Intercept	-2.10	0.10	432.00	0.00			
Demographics							
Age	0.00	0.00	1.93	0.16	1.00	0.99	1.00
Cardiovascular/Respiratory							
History of Mechanical Ventilation (ICD-9 codes: 93.90, 96.70, 96.71, 96.72)	0.13	0.07	3.57	0.06	1.14	1.00	1.31
Sleep Apnea (ICD-9 codes: 327.20, 327.21, 327.23, 327.27, 327.29, 780.51, 780.53, 780.57)	-0.06	0.06	0.85	0.36	0.94	0.83	1.07
Respirator Dependence/Respiratory Arrest (CC 77-78)	-0.09	0.16	0.33	0.56	0.91	0.67	1.25
Cardio-Respiratory Failure and Shock (CC 79)	0.18	0.07	7.96	0.00	1.20	1.06	1.37
Congestive Heart Failure (CC 80)	0.32	0.06	30.50	0.00	1.37	1.23	1.53
Acute Coronary Syndrome (CC 81-82)	0.26	0.10	7.52	0.01	1.30	1.08	1.57
Chronic Atherosclerosis (CC 83-84)	0.18	0.05	11.65	0.00	1.20	1.08	1.32
Arrhythmias (CC 92-93)	0.12	0.06	4.03	0.04	1.13	1.00	1.27
Other and Unspecified Heart Disease (CC 94)	0.20	0.10	4.09	0.04	1.22	1.01	1.49
Vascular or Circulatory Disease (CC 104-106)	0.15	0.06	5.13	0.02	1.16	1.02	1.31
Fibrosis of Lung and Other Chronic Lung Disorder (CC 109)	0.07	0.09	0.75	0.39	1.08	0.91	1.27
Pneumonia (CC 111-113)	0.13	0.05	7.10	0.01	1.14	1.03	1.25
Comorbidities							
History of Infection (CC 1, 3-6)	0.34	0.06	33.84	0.00	1.40	1.25	1.57
Metastatic Cancer and Acute Leukemia (CC 7)	0.17	0.21	0.61	0.43	1.18	0.78	1.79
Lung, Upper Digestive Tract, and Other Severe Cancers (CC 8)	0.48	0.17	7.67	0.01	1.62	1.15	2.27
Lymphatic, Head and Neck, Brain, and Other Major Cancers;	0.04	0.13	0.11	0.74	1.04	0.80	1.36

Description	Estimate	Standard Error	Wald Chi-Square	P value	OR	LOR	UOR
Breast, Colorectal and other Cancers and Tumors; Other Respiratory and Heart Neoplasms (CC 9-11)							
Other Digestive and Urinary Neoplasms (CC 12)	0.09	0.16	0.34	0.56	1.10	0.81	1.49
Diabetes and DM Complications (CC 15-20, 119-120)	0.07	0.05	1.98	0.16	1.07	0.97	1.18
Protein-Calorie Malnutrition (CC 21)	0.03	0.09	0.12	0.73	1.03	0.87	1.23
Disorders of Fluid/Electrolyte/Acid-Base (CC 22-23)	0.27	0.05	26.32	0.00	1.31	1.18	1.45
Other Endocrine/Metabolic/Nutritional Disorders (CC 24)	-0.07	0.05	2.03	0.15	0.93	0.85	1.03
Pancreatic Disease (CC 32)	0.05	0.07	0.49	0.48	1.05	0.91	1.21
Peptic Ulcer, Hemorrhage, Other Specified Gastrointestinal Disorders (CC 34)	0.15	0.08	3.83	0.05	1.16	1.00	1.34
Other Gastrointestinal Disorders (CC 36)	0.14	0.05	9.85	0.00	1.16	1.06	1.26
Severe Hematological Disorders (CC 44)	0.56	0.17	10.49	0.00	1.75	1.25	2.45
Iron Deficiency and Other/Unspecified Anemia and Blood Disease (CC 47)	0.22	0.05	20.76	0.00	1.25	1.14	1.37
Dementia or Senility (CC 49-50)	-0.03	0.14	0.04	0.85	0.97	0.74	1.29
Drug/Alcohol Induced Dependence/Psychosis (CC 51-52)	0.30	0.06	29.27	0.00	1.35	1.21	1.51
Major Psychiatric Disorders (CC 54-56)	0.40	0.05	60.10	0.00	1.49	1.35	1.64
Depression (CC 58)	0.15	0.05	9.43	0.00	1.16	1.06	1.28
Anxiety Disorders (CC 59)	0.23	0.11	4.63	0.03	1.26	1.02	1.56
Other Psychiatric Disorders (CC 60)	0.18	0.05	11.89	0.00	1.20	1.08	1.33
Quadriplegia, Paraplegia, Functional Disability (CC 67-69, 100-102, 177-178)	0.17	0.11	2.45	0.12	1.18	0.96	1.46
Polyneuropathy (CC 71)	-0.05	0.08	0.39	0.53	0.95	0.80	1.12
Hypertensive Heart and Renal Disease or Encephalopathy (CC 89)	0.52	0.18	8.37	0.00	1.68	1.18	2.40
Stroke (CC 95-96)	-0.29	0.20	1.98	0.16	0.75	0.50	1.12
Renal Failure (CC 131)	0.16	0.08	4.28	0.04	1.17	1.01	1.36
Decubitus Ulcer or Chronic Skin Ulcer (CC 148-149)	0.01	0.10	0.00	0.96	1.01	0.82	1.23
Cellulitis, Local Skin Infection (CC 152)	0.30	0.08	15.61	0.00	1.35	1.16	1.56

Description	Estimate	Standard Error	Wald Chi-Square	P value	OR	LOR	UOR
Vertebral Fractures (CC 157)	0.38	0.14	7.12	0.01	1.46	1.11	1.94
Old (Age>=65)	0.33	0.06	25.70	0.00	1.38	1.22	1.57
Interactions							
Cardiovascular/Respiratory							
Older and History of Mechanical Ventilation (ICD-9 codes: 93.90, 96.70, 96.71, 96.72)	-0.06	0.09	0.44	0.51	0.94	0.79	1.12
Older and Sleep Apnea (ICD-9 codes: 327.20, 327.21, 327.23, 327.27, 327.29, 780.51, 780.53, 780.57)	0.13	0.09	2.19	0.14	1.14	0.96	1.35
Older and Respirator Dependence/Respiratory Arrest (CC 77-78)	0.26	0.22	1.48	0.22	1.30	0.85	2.00
Older and Cardio-Respiratory Failure and Shock (CC 79)	-0.01	0.08	0.02	0.89	0.99	0.84	1.16
Older and Congestive Heart Failure (CC 80)	-0.13	0.07	3.44	0.06	0.88	0.77	1.01
Older and Acute Coronary Syndrome (CC 81-82)	-0.33	0.12	8.39	0.00	0.72	0.57	0.90
Older and Chronic Atherosclerosis (CC 83-84)	-0.04	0.06	0.40	0.53	0.96	0.85	1.09
Older and Arrhythmias (CC 92-93)	0.08	0.07	1.25	0.26	1.08	0.94	1.25
Older and Other and Unspecified Heart Disease (CC 94)	-0.17	0.12	1.94	0.16	0.85	0.67	1.07
Older and Vascular or Circulatory Disease (CC 104-106)	-0.07	0.08	0.81	0.37	0.93	0.80	1.09
Older and Fibrosis of Lung and Other Chronic Lung Disorder (CC 109)	-0.07	0.10	0.47	0.49	0.93	0.77	1.14
Older and Pneumonia (CC 111-113)	0.04	0.06	0.51	0.48	1.04	0.93	1.17
Comorbidities							
Older and History of Infection (CC 1, 3-6)	-0.20	0.07	7.77	0.01	0.82	0.71	0.94
Older and Metastatic Cancer and Acute Leukemia (CC 7)	0.04	0.24	0.02	0.88	1.04	0.65	1.67
Older and Lung, Upper Digestive Tract, and Other Severe Cancers (CC 8)	-0.36	0.20	3.40	0.07	0.70	0.48	1.02
Older and Lymphatic, Head and Neck, Brain, and Other Major Cancers; Breast, Colorectal and other Cancers and Tumors; Other Respiratory and Heart Neoplasms (CC 9-11)	0.10	0.15	0.46	0.50	1.11	0.83	1.48

Description	Estimate	Standard Error	Wald Chi-Square	P value	OR	LOR	UOR
Older and Other Digestive and Urinary Neoplasms (CC 12)	-0.04	0.19	0.05	0.82	0.96	0.67	1.38
Older and Diabetes and DM Complications (CC 15-20, 119-120)	0.07	0.06	1.30	0.25	1.07	0.95	1.20
Older and Protein-Calorie Malnutrition (CC 21)	0.06	0.10	0.32	0.57	1.06	0.87	1.30
Older and Disorders of Fluid/Electrolyte/Acid-Base (CC 22-23)	-0.16	0.06	6.28	0.01	0.85	0.75	0.97
Older and Other Endocrine/Metabolic/Nutritional Disorders (CC 24)	-0.01	0.06	0.01	0.93	0.99	0.89	1.11
Older and Pancreatic Disease (CC 32)	0.03	0.09	0.12	0.73	1.03	0.86	1.24
Older and Peptic Ulcer, Hemorrhage, Other Specified Gastrointestinal Disorders (CC 34)	-0.12	0.09	1.61	0.20	0.89	0.74	1.07
Older and Other Gastrointestinal Disorders (CC 36)	-0.03	0.06	0.22	0.64	0.97	0.87	1.09
Older and Severe Hematological Disorders (CC 44)	-0.28	0.22	1.63	0.20	0.76	0.49	1.16
Older and Iron Deficiency and Other/Unspecified Anemia and Blood Disease (CC 47)	0.01	0.06	0.01	0.91	1.01	0.90	1.13
Older and Dementia or Senility (CC 49-50)	0.10	0.15	0.42	0.52	1.10	0.82	1.48
Older and Drug/Alcohol Induced Dependence/Psychosis (CC 51-52)	-0.12	0.09	2.09	0.15	0.88	0.75	1.05
Older and Major Psychiatric Disorders (CC 54-56)	-0.26	0.08	10.85	0.00	0.77	0.66	0.90
Older and Depression (CC 58)	-0.19	0.06	9.21	0.00	0.83	0.73	0.93
Older and Anxiety Disorders (CC 59)	-0.09	0.16	0.31	0.58	0.92	0.68	1.25
Older and Other Psychiatric Disorders (CC 60)	-0.01	0.07	0.03	0.87	0.99	0.87	1.13
Older and Hemiplegia, Paraplegia, Paralysis, Functional Disability (CC 67-69, 100-102, 177-178)	-0.15	0.13	1.29	0.26	0.86	0.66	1.12
Older and Polyneuropathy (CC 71)	0.16	0.10	2.38	0.12	1.17	0.96	1.44
Older and Hypertensive Heart and Renal Disease or Encephalopathy (CC 89)	-0.44	0.20	4.82	0.03	0.64	0.43	0.95
Older and Stroke (CC 95-96)	0.23	0.24	0.96	0.33	1.26	0.79	2.02
Older and Renal Failure (CC 157)	-0.07	0.09	0.52	0.47	0.94	0.78	1.12

Description	Estimate	Standard Error	Wald Chi-Square	P value	OR	LOR	UOR
Older and Decubitus Ulcer or Chronic Skin Ulcer	0.16	0.13	1.60	0.21	1.18	0.92	1.51
Older and Cellulitis, Local Skin Infection	-0.28	0.11	7.00	0.01	0.75	0.61	0.93
Older and Vertebral Fractures	-0.06	0.16	0.14	0.70	0.94	0.68	1.29

Table 11a. COPD Mortality Model Performance for Models with Interaction Terms by Patient Subgroups

Data Source: 2006 California Patient Discharge Data for All-payer Patients 18+ Admitted to California Hospitals

Model with	N	C-statistic	SE	Lower C-stat	Upper C-stat	Predictive Ability*
All 65+	26,546	0.703	0.005	0.693	0.713	(3.45%, 25.58%)
FFS, 65+	16,629	0.705	0.007	0.691	0.718	(0.00%, 23.02%)
Non-FFS, 65+	9,917	0.704	0.008	0.688	0.719	(11.11%, 30.58%)
All 18-64	12,686	0.757	0.012	0.733	0.780	(0.90%, 22.82%)
All 18+	39,232	0.747	0.004	0.738	0.755	(0.92%, 25.41%)

*Mean observation readmission in the lowest and the highest decile of the predicted mortality.

Table 11b. COPD Readmission Model Performance for Models with Interaction Terms by Patient Subgroups

Data Source: 2006 California Patient Discharge Data for All-payer Patients 18+ Admitted to California Hospitals

Model with	N	C-statistic	SE	Lower C-stat	Upper C-stat	Predictive Ability*
All 65+	29,661	0.643	0.004	0.636	0.651	(11.61%, 39.87%)
FFS, 65+	18,647	0.641	0.005	0.632	0.651	(11.45%, 39.35%)
Non-FFS, 65+	11,014	0.646	0.007	0.633	0.659	(11.86%, 40.96%)
All 18-64	15,819	0.717	0.005	0.707	0.727	(8.61%, 48.07%)
All 18+	45,480	0.673	0.003	0.666	0.679	(8.71%, 43.89%)

*Mean observation readmission in the lowest and the highest decile of the predicted mortality.

Table 12a. Reclassification Table of Risk Categories for COPD Mortality Model With and Without Interaction Terms

Data Source: 2006 California Patient Discharge Data for All-payer Patients 18+ Admitted to California Hospitals

Model Without Interaction	Model With Interaction										
	0 to <5%		5% to <10%		10% to <20%		>=20%		Total		
	#	Column %	#	Column %	#	Column %	#	Column %	#	Column %	
Among All 18+ Patients											
Risk Category											
0 to <5%	14,149	36.06	1,643	4.19	14	0.04	0	0.00	15,806	40.29	
5% to <10%	692	1.76	11,907	30.35	804	2.05	4	0.01	13,407	34.17	Same category: 89.86
10% to <20%	3	0.01	412	1.05	6,823	17.39	186	0.47	7,424	18.92	Similar category: 99.93
>=20%	0	0.00	0	0.00	216	0.55	2,379	6.06	2,595	6.61	NRI=-0.0008; P=0.8937
Total	14,844	37.83	13,962	35.59	7,857	20.03	2,569	6.54	39,232	99.99	IDI=-0.0009; P= 0.0091
In All 65+ Patients											RIDI=-11.4075
Risk Category											
0 to <5%	3,926	14.79	1,422	5.36	0	0.00	0	0.00	5,348	20.15	
5% to <10%	41	0.15	11,063	41.67	649	2.44	0	0.00	11,753	44.26	Same category: 89.79
10% to <20%	0	0.00	280	1.05	6,563	24.72	127	0.48	6,970	26.25	Similar category: 99.99
>=20%	0	0.00	0	0.00	190	0.72	2,285	8.61	2,475	9.33	NRI=-0.0276; P=0.0000
Total	3,967	14.94	12,765	48.08	7,402	27.88	2,412	9.09	26,546	99.99	IDI=0.0021; P<0.0001
In FFS 65+ Patients											RIDI=0.068548
Risk Category											
0 to <5%	2,446	14.71	883	5.31	0	0.00	0	0.00	3,329	20.02	
5% to <10%	31	0.19	6,785	40.80	401	2.41	0	0.00	7,217	43.40	Same category: 89.56
10% to <20%	0	0.00	195	1.17	4,151	24.96	85	0.51	4,431	26.64	Similar category: 100.00
>=20%	0	0.00	0	0.00	141	0.85	1,511	9.09	1,652	9.94	NRI=-0.0285; P=0.0002
Total	2,477	14.90	7,863	47.28	4,693	28.22	1,596	9.60	16,629	100.00	IDI=0.00240; P<0.0001
In Non-FFS 65+ Patients											RIDI=-0.2005
Risk Category											
0 to <5%	1,480	14.92	539	5.44	0	0.00	0	0.00	2,019	20.36	

Model Without Interaction	Model With Interaction									
	0 to <5%		5% to <10%		10% to <20%		>=20%		Total	
	#	Column %	#	Column %	#	Column %	#	Column %	#	Column %
5% to <10%	10	0.10	4,278	43.14	248	2.50	0	0.00	4,536	45.74
10% to <20%	0	0.00	85	0.86	2,412	24.32	42	0.42	2,539	25.60
>=20%	0	0.00	0	0.00	49	0.49	774	7.80	823	8.29
Total	1,490	15.02	4,902	49.44	2,709	27.31	816	8.22	9,917	99.99
In All 18-64 Patients										
Risk Category										
0 to <5%	10,223	80.58	221	1.74	14	0.11	0	0.00	10,458	82.43
5% to <10%	651	5.13	844	6.65	155	1.22	4	0.03	1,654	13.03
10% to <20%	3	0.02	132	1.04	260	2.05	59	0.47	454	3.58
>=20%	0	0.00	0	0.00	26	0.20	94	0.74	120	0.94
Total	10,877	85.73	1,197	9.43	455	3.58	157	1.24	12,686	99.98

Same category: 90.18
Similar category: 100.00
NRI=-0.0276; P=0.0019
IDI=0.0017; P<0.0001
RIDI=0.3445

Same category: 90.02
Similar category: 99.82
NRI=0.0244; P=0.2995
IDI=-0.0096; P<0.0001
RIDI=-1.1078

Table 12b. Reclassification Table of Risk Categories for COPD Readmission Model With and Without Interaction Terms

Data Source: 2006 California Patient Discharge Data for All-payer Patients 18+ Admitted to California Hospitals

Model Without Interaction	Model With Interaction										
	0 to <5%		5% to <10%		10% to <20%		>=20%		Total		
	#	Column %	#	Column %	#	Column %	#	Column %	#	Column%	
Among All 18+ Patients											
Risk Category											
0 to <5%	16,059	35.31	2,093	4.60	0	0.00	0	0.00	18,152	39.9	
5% to <10%	1,526	3.36	7,964	17.51	1,010	2.22	3	0.01	10,503	23.1	Same category:84.7
10% to <20%	4	0.01	858	1.89	4,174	9.18	675	1.48	5,711	12.6	Similar category:100.00
>=20%	0	0.00	9	0.02	801	1.76	10,304	22.66	11,114	24.4	NRI=-0.0002; P=0.9567
Total	17,589	38.68	10,924	24.02	5,985	13.16	10,982	24.15	45,480	100.0	IDI=-0.0040; P<.0001
In All 65+ Patients											RIDI=-3.8688
Risk Category											
0 to <5%	9,662	32.57	2,038	6.87	0	0.00	0	0.00	11,700	39.4	
5% to <10%	194	0.65	6,044	20.38	813	2.74	0	0.00	7,051	23.8	Same category:85.20
10% to <20%	0	0.00	413	1.39	3,042	10.26	367	1.24	3,822	12.9	Similar category:100.0
>=20%	0	0.00	5	0.02	556	1.87	6,527	22.01	7,088	23.9	NRI=-0.0224; P<0.0001
Total	9,856	33.22	8,500	28.66	4,411	14.87	6,894	23.25	29,661	100.0	IDI=0.0057; P<.00001
In FFS 65+ Patients											RIDI=-2.1754
Risk Category											
0 to <5%	5,782	31.01	1,201	6.44	0	0.00	0	0.00	6,983	37.5	
5% to <10%	125	0.67	3,796	20.36	532	2.85	0	0.00	4,453	23.9	Same category: 85.21
10% to <20%	0	0.00	289	1.55	1,925	10.32	230	1.23	2,444	13.1	Similar category: 99.97
>=20%	0	0.00	5	0.03	377	2.02	4,385	23.52	4,767	25.6	NRI=-0.0225; P=0.0011
Total	5,907	31.68	5,291	28.38	2,834	15.19	4,615	24.75	18,647	100.0	IDI=0.0057; P<.00001
In Non-FFS 65+ Patients											RIDI=-4.7923
Risk Category											
0 to <5%	3,880	35.23	837	7.60	0	0.00	0	0.00	4,717	42.8	

Model Without Interaction	Model With Interaction									
	0 to <5%		5% to <10%		10% to <20%		>=20%		Total	
	#	Column %	#	Column %	#	Column %	#	Column %	#	Column%
5% to <10%	69	0.63	2,248	20.41	281	2.55	0	0.00	2,598	23.6
10% to <20%	0	0.00	124	1.13	1,117	10.14	137	1.24	1,378	12.5
>=20%	0	0.00	0	0.00	179	1.63	2,142	19.45	2,321	21.1
Total	3,949	35.86	3,209	29.14	1,577	14.32	2,279	20.69	11,014	100.0
In All 18-64 Patients										
Risk Category										
0 to <5%	6,397	40.44	55	0.35	0	0.00	0	0.00	6,452	40.8
5% to <10%	1,332	8.42	1,920	12.14	197	1.25	3	0.02	3,452	21.8
10% to <20%	4	0.03	445	2.81	1,132	7.16	308	1.95	1,889	12.0
>=20%	0	0.00	4	0.03	245	1.55	3,777	23.88	4,026	25.5
Total	7,733	48.89	2,424	15.33	1,574	9.96	4,088	25.85	15,819	100.0

Same category: 85.20
Similar category: 100.00
NRI=-0.0215; P=0.0152
IDI=0.0056; P<.0001
RIDI=-0.7753

Same category: 83.60
Similar category: 100
NRI=0.0428; P<0.0001
IDI=-0.0221; P<0.0001
RIDI=-2.8286

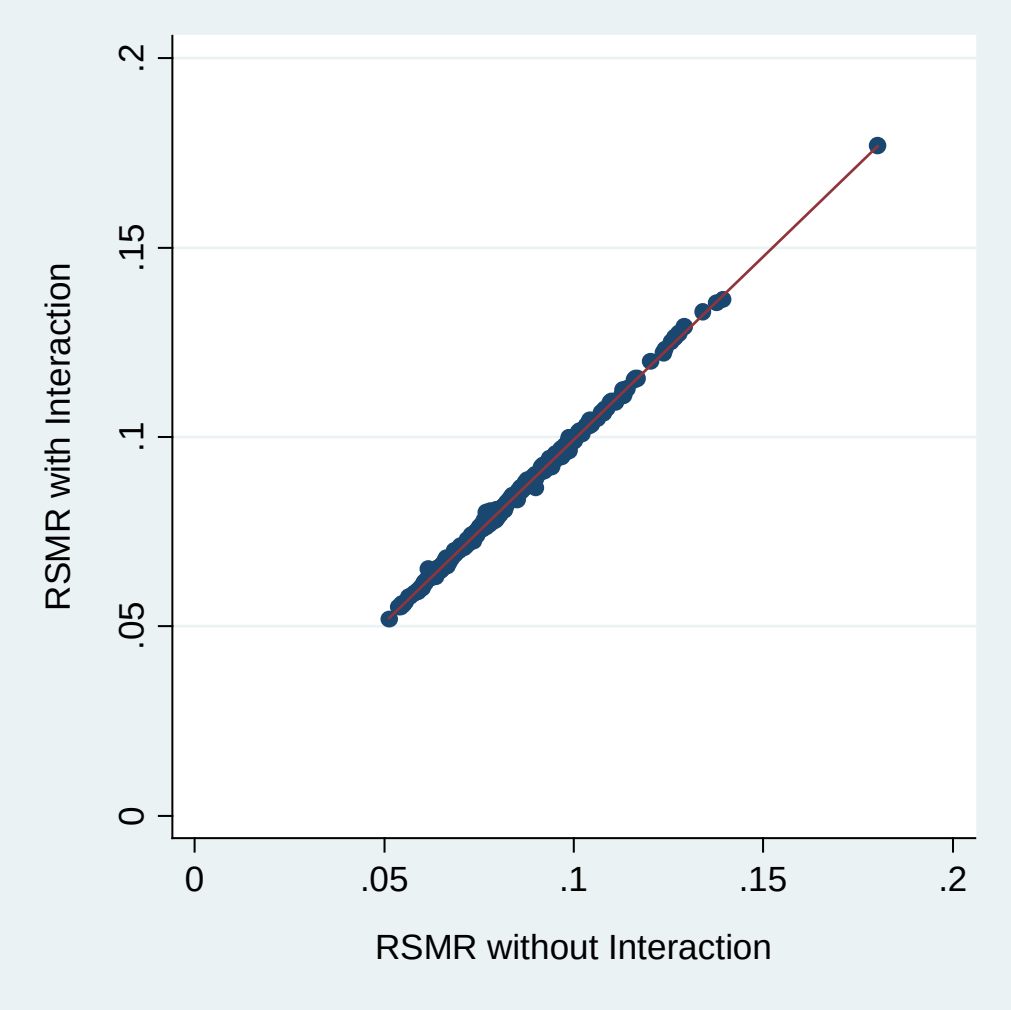
Table 13a. COPD Mortality Model Performance for Models With and Without Interaction Terms (N = 39,232)

Data Source: 2006 California Patient Discharge Data for All-payer Patients 18+ Admitted to California Hospitals

COPD Readmission Model	C-statistic	SE	Lower C-stat	Upper C-stat
With interaction terms	0.747	0.004	0.736	0.753
Without interaction terms	0.744	0.004	0.738	0.755

Figure 4a. Scatterplot of COPD Risk-Standardized Mortality Rates (RSMRs) from Models With and Without Interaction Terms

Data Source: 2006 California Patient Discharge Data for All-payer Patients 18+ Admitted to California Hospitals



Intra-class Correlation Coefficients (ICC): 0.999

Note: 1) RSMRs are in proportions.
2) Diagonal line represents the fitted line.

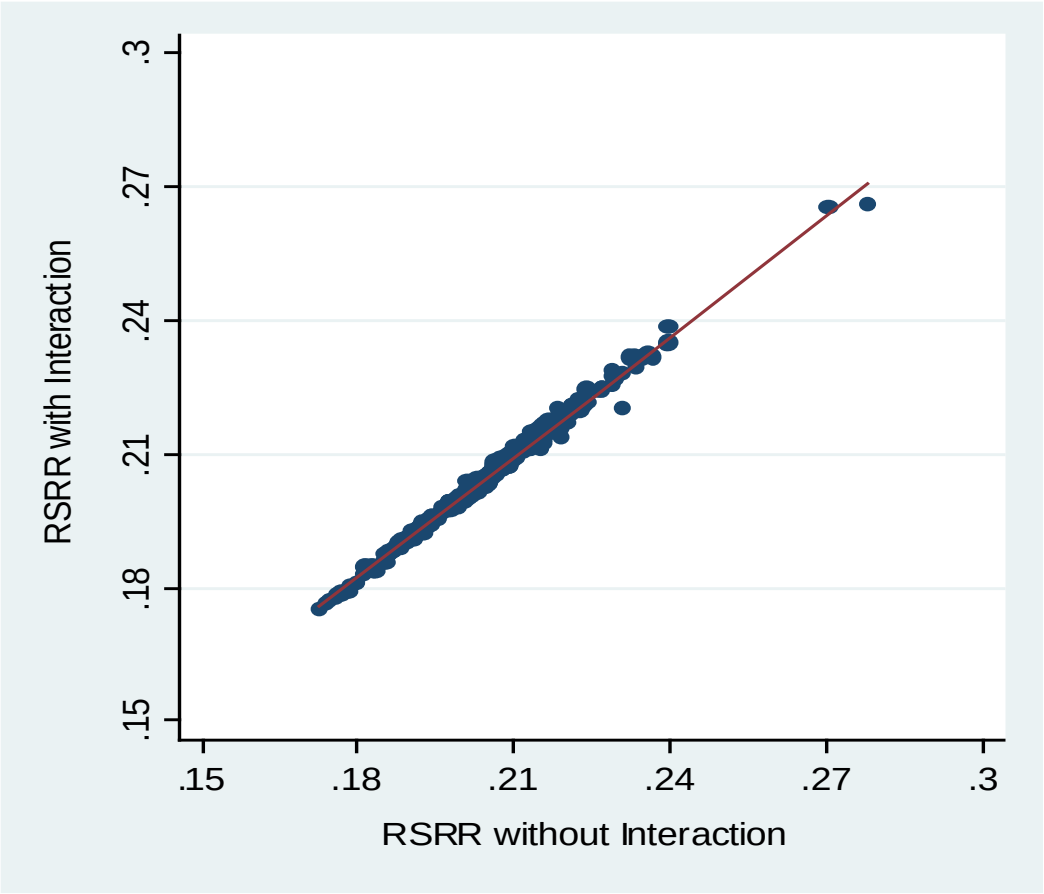
Table 13b. COPD Readmission Model Performance for Models With and Without Interaction Terms (N = 45,480)

Data Source: 2006 California Patient Discharge Data for All-payer Patients 18+ Admitted to California Hospitals

COPD Readmission Model	C-statistic	SE	Lower C-stat	Upper C-stat
With interaction terms	0.673	0.003	0.666	0.679
Without interaction terms	0.669	0.003	0.663	0.675

Figure 4b. Scatterplot of COPD Risk-Standardized Readmission Rates (RSRRs) from Models With and Without Interaction Terms

Data Source: 2006 California Patient Discharge Data for All-payer Patients 18+ Admitted to California Hospitals



Intra-class Correlation Coefficients (ICC): 0.999

Note: 1) RSRRs are in proportions.
2) Diagonal line represents the fitted line.