

## **Online Data Supplement**

Readmissions Reduction Program, Mortality and Readmissions for Chronic Obstructive  
Pulmonary Disease

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## Methods

### Study Cohort

We conducted a hospital-level retrospective study of all-cause 30-day readmissions and mortality involving patients with COPD using 100% Medicare files from 2006 to 2017.

The study was approved by the institutional review board of the University of Texas Medical Branch and complies with the Centers for Medicare and Medicaid Services (CMS) Data Use Agreement requirements. Acute admission patients with COPD as the principal discharge diagnosis were identified from December 2006 to November 2017 using the Medicare Provider Analysis and Review (MedPAR) files and the algorithm in the CMS Condition-Specific Measures Updates and Specifications Report, COPD version 1 (2011)(E1) and version 7 (2018)(E2,E3). We referenced version 1 only for COPD ICD-9-CM codes. We adopted the rest of the algorithms from version 7. We selected patients: with acute COPD admission (ICD codes Table E1 in the online data supplement); aged 65 years or older; and enrolled in Medicare Part A for at least 12 months before admission and at least 1 month after discharge (including those who died within one month of discharge). We excluded admissions in which the patient died during the hospital stay or had another COPD hospitalization discharge 30 days before admittance. Patients discharged against medical advice or transferred from hospice were excluded. Transfer admissions were bundled to the first hospital. (Figure 1).

### Study Periods

To study the impact of the announcement and implementation of HRRP on hospitals' 30-day risk-standardized readmission rates (hereafter referred to as 30-day

readmission rates) and 30-day risk-standardized post-discharge mortality rates (hereafter referred to as 30-day mortality rates) after a COPD hospitalization, we split the study years into three non-overlapping periods (pre-announcement, announcement and implementation) based on the HRRP announcement date (April 2010) and the implementation of penalties specific for COPD (October 2014). We assigned patients to each period by admission date. We excluded admissions in the transition year of 2012 due to limitations in beneficiary identification linkage. Due to the same limitation, our announcement period, which covers 2012, was split into two 20-month sub-periods. To maintain equal period intervals, we also split pre-announcement and implementation periods into 20-month sub-periods for consistency. As a consequence, our periods were divided as follows. The pre-announcement period: December 2006-July 2008 and August 2008-March 2010. The announcement period: April 2010-November 2011 and January 2013-August 2014. The announcement period of April 2010- November 2011 was used as a pivot for comparisons among periods. The implementation periods included October 2014-April 2016 and May 2016-November 2017 (Figure 1).

## Outcomes

Thirty-day readmission rates and thirty-day mortality rates were calculated at the hospital level following the CMS Condition-Specific Measures Updates and Specifications Report: Hospital-Level 30-Day Risk-Standardized Readmission Measures, COPD version 7(E2) and Hospital-Level 30-Day Risk-Standardized Mortality Measures, COPD version 7(E3), respectively. For patients with multiple index admissions in the same period, we used all index admissions to compute the hospital-level readmission rates and one randomly selected index admission to compute the

hospital-level mortality rates. Risk standardization of readmission and mortality rates for COPD includes risk-adjustment variables that are defined with ICD procedure (ICD-PCS) and diagnosis (ICD-CM) codes: ventilation (defined by ICD-9-PCS: 93.90, 96.70, 96.71, 96.72 and ICD-10-PCS: 5A09357), sleep apnea (defined by ICD-9-CM: 327.20, 327.21, 327.23, 327.27, 327.29, 780.51, 780.53, 780.57 and ICD-10-CM: G47.30), and a list of Clinical Classification Software categories defined in the Agency for Healthcare Research and Quality algorithm(E4).

### Hospital Characteristics and Variables

We collected hospital characteristics, including medical school affiliation, number of full-time nurses, organ transplant service, number of Medicare-certified beds, geographical region and type of ownership, from CMS Provider of Service (POS) files 2007, 2009, 2011, 2013, 2015 and 2017 versions (E5). We also collected hospital ratings from Survey of patients' experiences (HCAHPS)(E6, E7) for the years 2008, 2009, 2011, 2013, 2015, 2017. Year 2008 was used instead of 2007 because HCAHPS only became available in 2008. Medical school affiliation was categorized into major/graduate, limited and no affiliation, from most extensive involvement in teaching to least. Full-time nurses per bed was calculated as the ratio of the number of full-time nurses divided by the number of Medicare-certified beds. Hospital rating was categorized from the percentage of survey participants who gave a high rating (survey question, "Patients who gave a rating of 9 or 10 [high]"). Type of ownership included for-profit, non-profit and government (Table E3 in the online data supplement). The metro/non-metro indicator was created based on county, using the Rural-Urban Continuum Code (E8).

## Statistical Analysis

Hospital characteristics, readmission rates and mortality rates in each of the three periods were summarized. The generalized estimating equation (GEE) model was used to compare differences in readmission rates and mortality rates among periods while accounting for the cluster effect within hospitals. The GEE analyses over the three time periods (with normal distribution and identity link) showed an absolute difference between each study period and the reference period. We further stratified hospitals by medical school affiliation, number of full-time nurses-per-bed, hospital rating and ownership, then constructed GEE models to compare readmission and mortality rates. We compared readmission and mortality rates for different hospital characteristics in each period; changes in readmission and mortality rates across periods; and the slope of changes among hospital types. For models without stratification or adjustment, there was no missing data; for models with stratification by medical school affiliation, hospital ownership, full-time nurses-per-bed and hospital rating, we excluded hospitals with unknown characteristics described in Table 2 from analysis. The Bonferroni procedure was used to correct for the family-wise error. We used the GEE model-estimated increase in mortality rate and COPD population of the implementation period (May 2016-November 2017) to estimate additional deaths during HRRP implementation. All analyses were performed using SAS version 9.4 (SAS Inc., Cary, NC). All reported  $p$ -values were two-sided with  $p < 0.05$ .

## Supplement References

- E1. U.S. Centers for Medicare & Medicaid Services, "Hospital-level 30-day Mortality Following Admission for an Acute Exacerbation of Chronic Obstructive Pulmonary Disease. Measure Methodology Report, version 1 (2011)," CMS, last modified February 2020, <https://www.cms.gov/Medicare/Quality-Initiatives-Patient-Assessment-Instruments/HospitalQualityInits/Measure-Methodology>.
- E2. Centers for Medicare & Medicaid Services. "Condition-specific measures updates and specifications report hospital-level 30-day risk-standardized readmission measures." (2018).
- E3. Centers for Medicare & Medicaid Services. "Condition-specific measures updates and specifications report hospital-level 30-day risk-standardized mortality measures." (2018).
- E4. Healthcare Cost and Utilization Project, "Clinical Classifications Software (CCS) for ICD-9-CM Fact Sheet," H-CUP, last modified January 2012, <https://www.hcup-us.ahrq.gov/toolssoftware/ccs/ccsfactsheet.jsp>.
- E5. U.S. Centers for Medicare & Medicaid Services, "Provider of Services Current Files," CMS, last modified July 2020, <https://www.cms.gov/Research-Statistics-Data-and-Systems/Downloadable-Public-Use-Files/Provider-of-Services>.
- E6. U.S. Centers for Medicare & Medicaid Services, "Hospital Consumer Assessment of Healthcare Providers and Systems: Patients' Perspectives of Care Survey," CMS, last modified February 2020,

<https://www.cms.gov/Medicare/Quality-Initiatives-Patient-Assessment-Instruments/HospitalQualityInits/HospitalHCAHPS>.

- E7. Giordano LA, Elliott MN, Goldstein E, Lehrman WG, Spencer PA. Development, implementation, and public reporting of the HCAHPS survey. *Med Care Res Rev* 2010; 67:27-37.
- E8. United States Department of Agriculture, "Rural-Urban Continuum Codes," USDA, last modified October 2019, <https://www.ers.usda.gov/data-products/rural-urban-continuum-codes/documentation/>.

## Footnotes

**Table E1.** ICD codes for COPD.

*Definition of abbreviations:* ICD= International Classification of Diseases; COPD= Chronic Obstructive Pulmonary Disease; AECOPD= Acute Exacerbation of Chronic Obstructive Pulmonary Disease.

**Table E2.** Cohort selection of patients discharged from COPD hospitalizations during periods of HRRP from December 2006 to November 2017 in the United States.

*Definition of abbreviations:* COPD= Chronic Obstructive Pulmonary Disease; HRRP= Hospital Readmissions Reduction Program; DUA= Data User Agreements; MEDPAR= Medicare Provider Analysis and Review; CMS= Centers for Medicare & Medicaid Services

\* HRRP periods were divided as follows: pre-announcement: December 2006-July 2008 and August 2008-March 2010; announcement: April 2010-November 2011 and January 2013-August 2014; implementation: October 2014-April 2016 and May 2016-November 2017.

† Our data source includes two data user agreements (DUA) that cover 1999 to 2011 and 2012 to 2017, respectively. We excluded admissions in the DUA transition year of 2012 due to limitations in beneficiary identification linkage. Due to the same limitation, our announcement period, which covers 2012, was split into two 20-month sub-periods. We therefore also split pre-announcement and implementation periods into 20-month sub-periods for consistency.

‡ Our data source, 100% Medicare beneficiary study files, only include inpatient claims (MEDPAR) and not Medicare Part B claims. Thus, unlike algorithms in CMS condition-



specific measures updates and specifications report, we only require patients to have Part A continuous enrollment in the past 12 months before admission.

§ We do not have a hospice-claims file. Therefore, we could not strictly follow algorithms in CMS condition-specific measures updates and specifications report to exclude patients with hospice stay in 12 months before admission. Instead, we excluded direct transfers from hospice.

**Table E3.** Definition of hospital ownership type by CMS provider of service files.\*

*Definition of abbreviations:* POS= Provider of Service. CMS= Centers for Medicare & Medicaid Services

\*POS files before and after 2011 have different categories for hospital ownership.

† For POS files before 2011, we define non-profit church, non-profit private, and non-profit other as non-profit; proprietary as profit; federal, state, local and hospital district or authority as government.

‡ For POS files 2011 and after, we defined church, private (not for profit), and other as non-profit; private (for profit) and physician ownership as profit; federal, state, local and hospital district or authority as government.

**Table E4.** GEE model\* estimated 30-day readmission rate and 30-day mortality rate at the hospital-level after patients' discharge from COPD hospitalization comparing rate changes during periods of the HRRP from December 2006 to November 2017 in the United States

*Definition of abbreviations:* GEE = generalized estimating equation; COPD= chronic obstructive pulmonary disease; HRRP= Hospital Readmissions Reduction Program. CI= Confidence Interval;  $\Delta$ = rate changes

\* GEE model was used to account for the hospital cluster effect among multiple periods.

† Data presented as percentage (confidence interval)

‡P-value was corrected by Bonferroni procedure to account for family-wised error

§Comparing mortality rate change from announcement to implementation there was a significant 0.4% difference. In other words, mortality rate increased faster in implementation period.

**Table E5.** Thirty-day readmission rate and 30-day mortality rate at the hospital-level by medical school affiliation\* after patients' discharge from COPD hospitalization during periods of the HRRP from December 2006 to November 2017 in the United States.

*Definition of abbreviations:* COPD= Chronic Obstructive Pulmonary Disease; HRRP= Hospital Readmissions Reduction Program. CI= Confidence Interval

\*Medical school affiliation was categorized into major/graduate, limited, and no affiliation from most extensive involvement to least.

†Data presented as percentage (CI).

**Table E6.** GEE model\* 30-day readmission rate at the hospital-level by medical school affiliation after patients' discharge from COPD hospitalization during periods of the HRRP from December 2006 to November 2017 in the United States.

*Definition of abbreviations:* GEE = Generalized Estimating Equation; COPD= Chronic Obstructive Pulmonary Disease; HRRP= Hospital Readmissions Reduction Program; CI= Confidence Interval.

\* GEE model was used to account for the hospital cluster effect among multiple periods.

† Data presented as percentage (CI)

‡ P-value shows the significance of the differences. The p-value was corrected by Bonferroni procedure to account for family-wised error.

§ Announcement period from April 2010 to November 2011 was used as a pivot for comparisons among periods.

We excluded hospitals missing medical school affiliation in each period. Table 2 provides detailed number of hospitals with unknown teaching status during periods of the HRRP.

**Table E7.** GEE model 30-day mortality rate at the hospital-level by medical school affiliation after patients' discharge from COPD hospitalization during periods of the HRRP from December 2006 to November 2017 in the United States.

*Definition of abbreviations:* GEE = Generalized Estimating Equation; COPD= Chronic Obstructive Pulmonary Disease; HRRP= Hospital Readmissions Reduction Program; CI= Confidence Interval.

\* GEE model was used to account for the hospital cluster effect among multiple periods.

† Data presented as percentage (CI)

‡ P-value shows the significance of the differences. The p-value was corrected by Bonferroni procedure to account for family-wised error.

§ Announcement period from April 2010 to November 2011 was used as a pivot for comparisons among periods.

We excluded hospitals missing medical school affiliation in each period. Table 2 provides detailed number of hospitals with unknown teaching status during periods of the HRRP.

**Table E8.** Thirty-day readmission rate at the hospital-level by nurse-per-bed ratio after patients' discharge from COPD hospitalization during periods of the HRRP from December 2006 to November 2017 in the United States

*Definition of abbreviations:* GEE = Generalized Estimating Equation; COPD= Chronic Obstructive Pulmonary Disease; HRRP= Hospital Readmissions Reduction Program; CI= Confidence Interval

\* GEE model was used to account for the hospital cluster effect among multiple periods.

† Data presented as percentage (confidence interval)

‡ P-value shows the significance of the differences. The p-value was corrected by Bonferroni procedure to account for family-wised error.

§ Announcement period from April 2010 to November 2011 was used as a pivot for comparisons among periods.

We excluded hospitals missing nurse-per-bed data in each period. Table 2 provides detailed number of hospitals with unknown nurse-per-bed data during periods of the HRRP.

**Table E9.** Thirty-day mortality rate at the hospital-level by nurse-per-bed ratio after patients' discharge during periods of the HRRP from COPD hospitalization from December 2006 to November 2017 in the United States.

*Definition of abbreviations:* GEE = Generalized Estimating Equation; COPD= Chronic Obstructive Pulmonary Disease; HRRP= Hospital Readmissions Reduction Program; CI= Confidence Interval.

\* GEE model was used to account for the hospital cluster effect among multiple periods.

† Data presented as percentage (CI)

‡ P-value shows the significance of the differences. The p-value was corrected by Bonferroni procedure to account for family-wised error.

§ Announcement period from April 2010 to November 2011 was used as a pivot for comparisons among periods.

We excluded hospitals missing nurse-per-bed data in each period. Table 2 provides detailed number of hospitals with unknown nurse-per-bed data during periods of the HRRP.

**Table E10.** Thirty-day readmission rate at the hospital-level by hospital rating after patients' discharge from COPD hospitalization during periods of the HRRP from December 2006 to November 2017 in the United States

*Definition of abbreviations:* GEE = Generalized Estimating Equation; COPD= Chronic Obstructive Pulmonary Disease; HRRP= Hospital Readmissions Reduction Program; CI= Confidence Interval.

\* GEE model was used to account for the hospital cluster effect among multiple periods.

† Data presented as percentage (CI)

‡ P-value shows the significance of the differences. The p-value was corrected by Bonferroni procedure to account for family-wised error.

§ Announcement period from April 2010 to November 2011 was used as a pivot for comparisons among periods.

Hospitals missing patient rating data in each period were excluded. Table 2 provides the number of hospitals with unknown patient rating data during periods of the HRRP.

**Table E11.** Thirty-day mortality rate at the hospital-level by hospital rating after patients' discharge from COPD hospitalization during periods of the HRRP from December 2006 to November 2017 in the United States.

*Definition of abbreviations:* GEE = Generalized Estimating Equation; COPD= Chronic Obstructive Pulmonary Disease; HRRP= Hospital Readmissions Reduction Program; CI= Confidence Interval.

\* GEE model was used to account for the hospital cluster effect among multiple periods.

† Data presented as percentage (CI)

‡ P-value shows the significance of the differences. The p-value was corrected by Bonferroni procedure to account for family-wised error.

§ Announcement period from April 2010 to November 2011 was used as a pivot for comparisons among periods.

Hospitals missing patient rating data in each period were excluded. Table 2 provides the number of hospitals with unknown patient rating data during periods of the HRRP.

**Table E12.** GEE model\* estimated 30-day readmission rate and 30-day mortality rate at the hospital-level after patients' discharge from COPD hospitalization during periods of the HRRP from December 2006 to November 2017 including mortality within a 30-day period from the date of the index admission according to how CMS calculates 30-day mortality rates.

*Definition of abbreviations:* GEE = Generalized Estimating Equation; COPD= Chronic Obstructive Pulmonary Disease; HRRP= Hospital Readmissions Reduction Program; CI= Confidence Interval

\* GEE model was used to account for the hospital cluster effect among multiple periods. We compared each periods' mortality rate with announcement period\* (each period minus announcement period\*).

† Announcement period from April 2010 to November 2011 was used as a pivot for comparisons among periods.

‡ Data presented as percentage (CI)

§ Independent risk-adjusted model for 30-day mortality rates that includes in-hospital death according to how CMS calculates 30-day mortality rates (mortality within a 30-day period from the date of the index admission).

|| P-value shows the significance of the differences. The p-value was corrected by Bonferroni procedure to account for family-wised error.

**Table E13.** GEE model\* estimated 30-day readmission rate and 30-day mortality rate at the hospital-level after patients' discharge from COPD hospitalization comparing rate changes during periods of the HRRP from December 2006 to November 2017 including mortality within a 30-day period from the date of the index admission according to how CMS calculates 30-day mortality rates.

*Definition of abbreviations:* GEE = Generalized Estimating Equation; COPD= Chronic Obstructive Pulmonary Disease; HRRP= Hospital Readmissions Reduction Program; CI= Confidence Interval.

\* GEE model was used to account for the hospital cluster effect among multiple periods.

† Data presented as percentage (CI)

‡ Independent risk-adjusted model for 30-day mortality rates that includes in-hospital death according to how CMS calculates 30-day mortality rates (mortality within a 30-day period from the date of the index admission).

§ P-values are corrected by Bonferroni procedure to account for family-wised error

|| Comparing mortality rate change from announcement to implementation there was a significant 0.51% difference. In other words, mortality rate increased faster in implementation period.

### **Figure E1**

A-B) 30-day Readmission Rate (A) and 30-day Mortality Rate (B) at the Hospital-level by Medical School Affiliation after patients' discharge from COPD hospitalization during periods of the HRRP from December 2006 to November 2017 in the United States. We excluded admissions in the year of 2012 (greyed out area) due to limitations in linking beneficiary identification. HRRP= Hospital Readmissions Reduction Program; COPD= Chronic Obstructive Pulmonary Disease.

### **Figure E2**

A-B) 30-day Readmission Rate (A) and 30-day Mortality Rate (B) at the Hospital-level by Nurse-per-bed after patients' discharge from COPD hospitalization during periods of the HRRP from December 2006 to November 2017 in the United States. We excluded admissions in the year of 2012 (greyed out area) due to limitations in linking beneficiary identification. HRRP= Hospital Readmissions Reduction Program; COPD= Chronic Obstructive Pulmonary Disease.



### **Figure E3**

(A-B) 30-day Readmission Rate (A) and 30-day Mortality Rate (B) at the Hospital-level by hospital rating after patients' discharge from COPD hospitalization during periods of the HRRP from December 2006 to November 2017 in the United States. We excluded admissions in the year of 2012 (greyed out area) due to limitations in linking beneficiary identification. HRRP= Hospital Readmissions Reduction Program; COPD= Chronic Obstructive Pulmonary Disease.

### **Figure E4**

(A-B) 30-day Readmission Rate (A) and 30-day Mortality Rate (B) at the Hospital-level after patients' discharge from COPD hospitalization during periods of the HRRP from December 2006 to November 2017 in the United States. This model includes mortality within a 30-day period from the date of the index admission according to how CMS calculates 30-day mortality rates. We excluded admissions in the year of 2012 (greyed out area) due to limitations in linking beneficiary identification. HRRP= Hospital Readmissions Reduction Program; COPD= Chronic Obstructive Pulmonary Disease; CMS= Centers for Medicare and Medicaid Services.

**Table E1.** ICD codes for COPD.

<b>ICD-10-CM Codes</b>	<b>Description</b>
J41.8	Mixed simple and mucopurulent chronic bronchitis
J42	Unspecified chronic bronchitis
J43.0	Unilateral pulmonary emphysema [MacLeod's syndrome]
J43.1	Panlobular emphysema
J43.2	Centrilobular emphysema
J43.8	Other emphysema
J43.9	Emphysema, unspecified
J44.0	Chronic obstructive pulmonary disease with acute lower respiratory infection
J44.1	Chronic obstructive pulmonary disease with (acute) exacerbation
J44.9	Chronic obstructive pulmonary disease, unspecified
<i>Principal discharge diagnosis codes included in cohort if combined with a secondary diagnosis of J44.0 or J44.1</i>	
J96.00	Acute respiratory failure, unspecified whether with hypoxia or hypercapnia
J96.01	Acute respiratory failure with hypoxia
J96.02	Acute respiratory failure with hypercapnia
J96.20	Acute and chronic respiratory failure, unspecified whether with hypoxia or hypercapnia
J96.21	Acute and chronic respiratory failure with hypoxia
J96.22	Acute and chronic respiratory failure with hypercapnia
J96.90	Respiratory failure, unspecified, unspecified whether with hypoxia or hypercapnia
J96.91	Respiratory failure, unspecified with hypoxia
J96.92	Respiratory failure, unspecified with hypercapnia
R09.2	Respiratory arrest
<b>ICD-9-CM Codes</b>	<b>Description</b>
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.
<i>Principal diagnosis when combined with a secondary diagnosis of AECOPD (491.21, 491.22, 493.21, or 493.22)</i>	
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
<i>Definition of abbreviations:</i> ICD= International Classification of Diseases; COPD= Chronic Obstructive Pulmonary Disease; AECOPD= Acute Exacerbation of Chronic Obstructive Pulmonary Disease.	

**Table E2.** Cohort selection of patients discharged from COPD hospitalizations during periods of HRRP from December 2006 to November 2017 in the United States.

HRRP Periods <sup>†</sup>	Pre-announcement		Announcement		Implementation	
Dates	Dec 2006 - Jul 2008	Aug 2008 - Mar 2010	Apr 2010 - Nov 2011	Jan 2013 - Aug 2014	Oct 2014 - Apr 2016	May 2016- Nov 2017
All admissions (individual patient #)	898,761 (617,596)	1,012,416 (677,868)	1,025,183 (686,984)	942,435 (662,389)	921,203 (653,617)	1,016,857 (710,012)
% of patients	100%	100%	100%	100%	100%	100%
Age ≥ 65	721,123 (510,131) 80.2%	801,885 (553,796) 79.2%	801,033 (554,666) 78.1%	745,087 (538,792) 81.3%	723,632 (529,054) 80.9%	794,782 (574,546) 80.9%
Alive during stay	694,262 (492,014) 96.3%	777,559 (537,758) 97.0%	779,444 (540,190) 97.3%	724,356 (524,145) 97.3%	703,706 (514,956) 97.4%	771,606 (558,049) 97.1%
Have part-a 12 months before admission and 1 month after discharge (or death in 1 month) <sup>‡</sup>	679,366 (481,817) 97.9%	764,831 (529,082) 98.4%	758,621 (526,964) 97.6%	709,871 (514,033) 98.1%	690,398 (505,455) 98.2%	756,123 (547,424) 98.1%
Exclude discharged against medical advice	675,722 (480,068) 99.6%	760,503 (527,033) 99.6%	754,201 (524,828) 99.6%	705,549 (511,794) 99.6%	685,575 (502,906) 99.5%	750,028 (544,307) 99.4%
Exclude transferred from hospice <sup>§</sup>	675,722 (480,068) 100%	760,494 (527,026) 99.99%	754,151 (524,803) 99.99%	705,512 (511,776) 99.9%	685,547 (502,890) 99.9%	749,980 (544,277) 99.9%
No previous COPD admission in 30 days	613,437 (479,210) 99.8%	688,664 (526,210) 99.9%	682,987 (523,619) 99.8%	647,815 (510,344) 99.7%	631,118 (502,149) 99.9%	685,027 (543,445) 99.9%
Transfer (included in above)	4,818 (4,772)	5,439 (5,349)	5,208 (5,105)	4,310 (4,240)	4,149 (4,099)	4,795 (4,721)
30-Day all-cause readmission (individual patient #)	125,422	140,019	136,593	118,091	116,483	127,688
30-Day all-cause mortality (individual patient #)	37,664	40,327	39,061	38,319	37,736	43,641

*Definition of abbreviations:* COPD= Chronic Obstructive Pulmonary Disease; HRRP= Hospital Readmissions Reduction Program; DUA= Data User Agreements; MEDPAR= Medicare Provider Analysis and Review; CMS= Centers for Medicare & Medicaid Services

\* HRRP periods were divided as follows. HRRP periods were divided as follows: pre-announcement: December 2006-July 2008 and August 2008-March 2010; announcement: April 2010-November 2011 and January 2013-August 2014; implementation: October 2014-April 2016 and May 2016-November 2017.

† Our data source includes two data user agreements (DUA) that cover 1999 to 2011 and 2012 to 2017, respectively. We excluded admissions in the DUA transition year of 2012 due to limitations in beneficiary identification linkage. Due to the same limitation, our announcement period, which covers 2012, was split into two 20-month sub-periods. We therefore also split pre-announcement and implementation periods into 20-month sub-periods for consistency.

‡ Our data source, 100% Medicare beneficiary study files, only include inpatient claims (MEDPAR) and not Medicare Part B claims. Thus, unlike algorithms in CMS condition-specific measures updates and specifications report, we only require patients to have Part A continuous enrollment in the past 12 months before admission.

§ We do not have a hospice-claims file. Therefore, we could not strictly follow algorithms in CMS condition-specific measures updates and specifications report to exclude patients with hospice stay in 12 months before admission. Instead, we excluded direct transfers from hospice.

**Table E3.** Definition of hospital ownership type by CMS provider of service files.\*

Hospital ownership categories	Before 2011 †	2011 and after ‡
Non-profit	Voluntary Non-Profit - Church Voluntary Non-Profit - Private Voluntary Non-Profit - Other	Church Private (Not For Profit) Other (Specify)
Profit	Proprietary	Private (For Profit) Physician ownership
Government	Government - Federal Government - State Government - Local Gov. - Hosp. Dist. Or Auth.	Federal State Local Hospital District Or Authority

*Definition of abbreviations:* POS= Provider of Service. CMS= Centers for Medicare & Medicaid Services

\*POS files before and after 2011 have different categories for hospital ownership.

† For POS files before 2011, we define non-profit church, non-profit private, and non-profit other as non-profit; proprietary as profit; federal, state, local and hospital district or authority as government.

‡ For POS files 2011 and after, we defined church, private (not for profit), and other as non-profit; private (for profit) and physician ownership as profit; federal, state, local and hospital district or authority as government.

**Table E4.** GEE model\* estimated 30-day readmission rate and 30-day mortality rate at the hospital-level after patients' discharge from COPD hospitalization comparing rate changes during periods of the HRRP from December 2006 to November 2017 in the United States.

	HRRP Period	Risk adjusted rate %(CI) †	p- value‡
30-Day Readmission Rate	Δ (Pre-announcement from <i>December 2006-July 2008</i> to <i>August 2008-March 2010</i> )	-0.13 (-0.18-0.09)	<.0001
	Δ (Announcement from <i>January 2013-August 2014</i> to Implementation <i>October 2014-April 2016</i> )	0.22 (0.18-0.27)	<.0001
	Δ (Implementation from <i>October 2014-April 2016</i> to <i>May 2016-November 2017</i> )	0.19 (0.14-0.24)	<.0001
	Δ (Announcement from <i>January 2013-August 2014</i> to Implementation <i>October 2014-April 2016</i> ) <b>minus</b> Δ(Implementation from <i>October 2014-April 2016</i> to <i>May 2016-November 2017</i> )	-0.03 (-0.11-0.04)	1.0000
30-Day Mortality Rate	Δ (Pre-announcement from <i>December 2006-July 2008</i> to <i>August 2008-March 2010</i> )	-0.23 (-0.26-0.19)	<.0001
	Δ (Announcement from <i>January 2013-August 2014</i> to Implementation <i>October 2014-April 2016</i> )	0.10 (0.06-0.13)	<.0001
	Δ (Implementation from <i>October 2014-April 2016</i> to <i>May 2016-November 2017</i> )	0.49 (0.45-0.53)	<.0001
	Δ (Announcement from <i>January 2013-August 2014</i> to Implementation <i>October 2014-April 2016</i> ) <b>minus</b> Δ(Implementation from <i>October 2014-April 2016</i> to <i>May 2016- November 2017</i> ) §	0.40 (0.33-0.46)	<.0001

*Definition of abbreviations:* GEE = generalized estimating equation; COPD= chronic obstructive pulmonary disease; HRRP= Hospital Readmissions Reduction Program. CI= Confidence Interval; Δ= rate changes

\* GEE model was used to account for the hospital cluster effect among multiple periods.

† Data presented as percentage (CI)

‡P-value was corrected by Bonferroni procedure to account for family-wised error

§Comparing mortality rate change from announcement to implementation there was a significant 0.4% difference. In other words, mortality rate increased faster in implementation period.

**Table E5.** Thirty-day readmission rate and 30-day mortality rate at the hospital-level by medical school affiliation\* after patients' discharge from COPD hospitalization during periods of the HRRP from December 2006 to November 2017 in the United States.

	HRRP Period		Medical School Affiliation*		
			Major/Graduate %(CI) †	Limited %(CI) †	No Affiliation %(CI) †
30-Day Readmission Rate	Pre-announcement	December 2006-July 2008	20.74(20.61-20.88)	20.44(20.34-20.55)	20.53(20.48-20.58)
		August 2008-March 2010	20.64(20.52-20.76)	20.45(20.35-20.55)	20.35(20.3-20.39)
	Announcement	April 2010-November 2011	20.35(20.24-20.46)	20.02(19.93-20.11)	20.05(20.01-20.09)
		January 2013-August 2014.	18.44(18.34-18.55)	18.34(18.25-18.44)	18.3(18.26-18.35)
	Implementation	October 2014-April 2016	18.68(18.57-18.79)	18.51(18.43-18.6)	18.54(18.49-18.58)
		May 2016-November 2017	18.85(18.73-18.97)	18.7(18.6-18.79)	18.74(18.68-18.79)
30-Day Mortality Rate	Pre-announcement	December 2006-July 2008	6.7(6.62-6.77)	6.91(6.84-6.97)	6.95(6.92-6.98)
		August 2008-March 2010	6.43(6.35-6.51)	6.73(6.66-6.8)	6.72(6.69-6.76)
	Announcement	April 2010-November 2011	6.3(6.22-6.37)	6.59(6.53-6.66)	6.64(6.61-6.68)
		January 2013-August 2014.	6.41(6.33-6.49)	6.73(6.66-6.8)	6.77(6.73-6.81)
	Implementation	October 2014-April 2016	6.4(6.31-6.49)	6.78(6.7-6.86)	6.9(6.86-6.94)
		May 2016-November 2017	6.82(6.72-6.91)	7.25(7.17-7.33)	7.41(7.37-7.46)

*Definition of abbreviations:* COPD= Chronic Obstructive Pulmonary Disease; HRRP= Hospital Readmissions Reduction Program. CI= Confidence Interval

\*Medical school affiliation was categorized into major/graduate, limited, and no affiliation from most extensive involvement to least.

†Data presented as percentage (CI)

**Table E6.** GEE model\* 30-day readmission rate at the hospital-level by medical school affiliation after patients' discharge from COPD hospitalization during periods of the HRRP from December 2006 to November 2017 in the United States.

Compare between hospitals with different teaching status on each period

Hospital's medical school affiliation type		HRRP Periods	Risk adjusted rate %(CI) †	p-value‡
Limited <i>minus</i> Major/graduate	Pre-announcement	December 2006-July 2008	-0.22 (-0.38--0.06)	0.0907
		August 2008-March 2010	-0.14 (-0.29-0.01)	0.7923
	Announcement	April 2010-November 2011	-0.22 (-0.35-0.08)	0.0176
		January 2013-August 2014.	-0.13 (-0.26-0.01)	0.8786
	Implementation	October 2014 to April 2016	-0.16 (-0.29--0.03)	0.1867
		May 2016-November 2017	-0.09 (-0.24-0.05)	1.0000
No affiliation <i>minus</i> Major/graduate	Pre-announcement	December 2006-July 2008	-0.13 (-0.24-0.01)	0.4187
		August 2008-March 2010	-0.25 (-0.37-0.14)	0.0001
	Announcement	April 2010-November 2011	-0.19 (-0.29-0.09)	0.0031
		January 2013-August 2014.	-0.13 (-0.23-0.02)	0.1803
	Implementation	October 2014-April 2016	-0.13 (-0.24-0.02)	0.1856
		May 2016-November 2017	-0.09 (-0.21-0.03)	1.0000
Compare each period with announcement period (April 2010-November 2011)§			Period minus announcement period %(CI) **§	
Major/graduate	Pre-announcement	December 2006-July 2008	0.41 (0.29-0.53)	<.0001
		August 2008-March 2010	0.35 (0.24-0.47)	<.0001
	Announcement	January 2013-August 2014	-1.81 (-1.92-1.7)	<.0001
	Implementation	October 2014-April 2016 May 2016-November 2017	-1.58 (-1.7-1.46) -1.43 (-1.55-1.31)	<.0001 <.0001
Limited	Pre-announcement	December 2006-July 2008	0.41 (0.28-0.54)	<.0001
		August 2008-March 2010	0.43 (0.32-0.55)	<.0001
	Announcement	January 2013-August 2014	-1.72 (-1.84-1.6)	<.0001
	Implementation	October 2014-April 2016 May 2016-November 2017	-1.52 (-1.64-1.41) -1.31 (-1.43-1.18)	<.0001 <.0001

**Table E6.** (Continued)

Compare each period with announcement period (April 2010-November 2011)<sup>§</sup>

Hospital's medical school affiliation type	HRRP Periods		Risk adjusted rate %(CI) *†§	p-value‡
No affiliation	Pre-announcement	December 2006-July 2008	0.48 (0.42-0.53)	<.0001
		August 2008-March 2010	0.29 (0.24-0.34)	<.0001
	Announcement	January 2013-August 2014	-1.74 (-1.8-1.69)	<.0001
	Implementation	October 2014-April 2016 May 2016-November 2017	-1.52 (-1.57-1.46) -1.33 (-1.39-1.27)	<.0001 <.0001

*Definition of abbreviations:* GEE = Generalized Estimating Equation; COPD= Chronic Obstructive Pulmonary Disease; HRRP= Hospital Readmissions Reduction Program; CI= Confidence Interval.

\* GEE model was used to account for the hospital cluster effect among multiple periods.

† Data presented as percentage (CI)

‡ P-value shows the significance of the differences. The p-value was corrected by Bonferroni procedure to account for family-wised error.

§ Announcement period from April 2010 to November 2011 was used as a pivot for comparisons among periods.

We excluded hospitals missing medical school affiliation in each period. Table 2 provides detailed number of hospitals with unknown teaching status during periods of the HRRP.



**Table E7.** GEE model 30-day mortality rate at the hospital-level by medical school affiliation after patients' discharge from COPD hospitalization during periods of the HRRP from December 2006 to November 2017 in the United States.

Compare between hospitals with different teaching status on each period				
Hospitals' medical school Affiliation type		HRRP Periods	Risk adjusted rate %(CI) †	p-value‡
Limited <i>minus</i> major/graduate	Pre-announcement	December 2006-July 2008	0.12 (0.02-0.21)	0.1991
		August 2008-March 2010	0.19 (0.09-0.29)	0.0025
	Announcement	April 2010-November 2011	0.19 (0.09-0.29)	0.0012
		January 2013-August 2014	0.26 (0.16-0.37)	<.0001
	Implementation	October 2014-April 2016	0.29 (0.17-0.4)	<.0001
		May 2016-November 2017	0.37 (0.25-0.49)	<.0001
No affiliation <i>minus</i> major/graduate	Pre-announcement	December 2006-July 2008	0.18 (0.11-0.25)	<.0001
		August 2008-March 2010	0.19 (0.11-0.26)	<.0001
	Announcement	April 2010-November 2011	0.24 (0.16-0.31)	<.0001
		January 2013-August 2014	0.27 (0.19-0.34)	<.0001
	Implementation	October 2014-April 2016	0.4 (0.31-0.49)	<.0001
		May 2016-November 2017	0.51 (0.41-0.61)	<.0001
Compare each period with announcement period (April 2010-November 2011)§				
			Period minus announcement period %(CI) **§	
Major/graduate	Pre-announcement	December 2006-July 2008	0.38 (0.3-0.46)	<.0001
		August 2008-March 2010	0.14 (0.06-0.22)	0.0147
	Announcement	January 2013-August 2014	0.1 (0.01-0.18)	0.3261
Implementation	October 2014-April 2016	0.1 (0.01-0.19)	0.4053	
	May 2016-November 2017	0.51 (0.41-0.61)	<.0001	
Limited	Pre-announcement	December 2006-July 2008	0.31 (0.21-0.4)	<.0001
		August 2008-March 2010	0.14 (0.05-0.23)	0.0268
	Announcement	January 2013-August 2014	0.17 (0.07-0.26)	0.0072
Implementation	October 2014-April 2016	0.2 (0.1-0.29)	0.0006	
	May 2016-November 2017	0.69 (0.58-0.79)	<.0001	
No affiliation	Pre-announcement	December 2006-July 2008	0.32 (0.28-0.36)	<.0001
		August 2008-March 2010	0.08 (0.04-0.12)	0.0009
Announcement	January 2013-August 2014	0.12 (0.08-0.16)	<.0001	

**Table E7. (Continued)**

Hospitals' medical school affiliation type	HRRP Periods		Period minus announcement period %(CI) *†§	p-value‡
No affiliation	Implementation	October 2014-April 2016	0.26 (0.21-0.31)	<.0001
		May 2016-November 2017	0.78 (0.73-0.83)	<.0001
Compare between hospitals with different teaching status with announcement period (April 2010-November 2011)§				
Limited <i>minus</i> Major/graduate	Pre-announcement	December 2006-July 2008	-0.07 (-0.2-0.05)	1.0000
		August 2008-March 2010	0 (-0.12-0.12)	1.0000
	Announcement	January 2013-August 2014	0.07 (-0.05-0.2)	1.0000
	Implementation	October 2014-April 2016	0.1 (-0.04-0.23)	1.0000
		May 2016-November 2017	0.18 (0.04-0.33)	0.1451
	No affiliation <i>minus</i> Major/graduate	Pre-announcement	December 2006- July 2008	-0.06 (-0.15-0.03)
August 2008-March 2010			-0.05 (-0.14-0.04)	1.0000
Implementation		October 2014-April 2016	0.16 (0.05-0.26)	0.0272
		May 2016-November 2017	0.27 (0.16-0.38)	<.0001

*Definition of abbreviations:* GEE = Generalized Estimating Equation; COPD= Chronic Obstructive Pulmonary Disease; HRRP= Hospital Readmissions Reduction Program; CI= Confidence Interval.

\* GEE model was used to account for the hospital cluster effect among multiple periods.

† Data presented as percentage (CI)

‡ P-value shows the significance of the differences. The p-value was corrected by Bonferroni procedure to account for family-wised error.

§ Announcement period from April 2010 to November 2011 was used as a pivot for comparisons among periods.

We excluded hospitals missing medical school affiliation in each period. Table 2 provides detailed number of hospitals with unknown teaching status during periods of the HRRP.

**Table E8.** Thirty-day readmission rate at the hospital-level by nurse-per-bed ratio after patients' discharge from COPD hospitalization during periods of the HRRP from December 2006 to November 2017 in the United States.

Compare between hospitals with different nurse-per-bed ratio on each period				
Full-time nurse-per-bed	HRRP Periods		Nurse-per-bed >1 minus ≤1 %(CI) †	p-value‡
>1 minus ≤1	Pre-announcement	December 2006-July 2008	-0.06 (-0.14-0.03)	1.0000
		August 2008-March 2010	-0.02 (-0.1-0.05)	1.0000
	Announcement	April 2010-November 2011	-0.07 (-0.14-0)	0.3810
		January 2013-August 2014.	-0.06 (-0.13-0.02)	0.8201
	Implementation	October 2014-April 2016	-0.09 (-0.17--0.02)	0.0813
		May 2016-November 2017	-0.12 (-0.21--0.04)	0.0252
Compare each period with announcement period (April 2010-November 2011)				
			Period minus announcement period %(CI) *†§	
>1	Pre-announcement	December 2006-July 2008	0.46 (0.39-0.53)	<.0001
		August 2008-March 2010	0.34 (0.28-0.41)	<.0001
	Announcement	January 2013-August 2014.	-1.74 (-1.81-1.68)	<.0001
	Implementation	October 2014-April 2016	-1.54 (-1.6-1.47)	<.0001
		May 2016-November 2017	-1.36 (-1.43-1.29)	<.0001
	≤1	Pre-announcement	December 2006-July 2008	0.45 (0.38-0.51)
August 2008-March 2010			0.3 (0.24-0.36)	<.0001
Announcement		January 2013-August 2014.	-1.75 (-1.82--1.69)	<.0001
Implementation		October 2014-April 2016	-1.51 (-1.58-1.44)	<.0001
		May 2016-November 2017	-1.3 (-1.38-1.23)	<.0001
Compare between hospitals with different nurse-per-bed ratio with announcement period (April 2010-November 2011)				
			Period minus announcement period %(CI) *†§	
>1 minus ≤1	Pre-announcement	December 2006-July 2008	0.01 (-0.09-0.11)	1.0000
		August 2008-March 2010	0.04 (-0.05-0.13)	1.0000
	Announcement	January 2013-August 2014	0.01 (-0.08-0.1)	1.0000
	Implementation	October 2014-April 2016	-0.03 (-0.12-0.07)	1.0000
		May 2016-November 2017	-0.06 (-0.16-0.04)	1.0000

*Definition of abbreviations:* GEE = Generalized Estimating Equation; COPD= Chronic Obstructive Pulmonary Disease; HRRP= Hospital Readmissions Reduction Program; CI= Confidence Interval

\* GEE model was used to account for the hospital cluster effect among multiple periods.

† Data presented as percentage (CI)

‡ P-value shows the significance of the differences. The p-value was corrected by Bonferroni procedure to account for family-wised error.

§ Announcement period from April 2010 to November 2011 was used as a pivot for comparisons among periods.

We excluded hospitals missing nurse-per-bed data in each period. Table 2 provides detailed number of hospitals with unknown nurse-per-bed data during periods of the HRRP.

**Table E9.** Thirty-day mortality rate at the hospital-level by nurse-per-bed ratio after patients' discharge during periods of the HRRP from COPD hospitalization from December 2006 to November 2017 in the United States.

Compare between hospitals with different nurse-per-bed ratio on each period				
Full-time Nurse-per- bed	HRRP Periods		Nurse-per-bed >1 minus ≤1 %(CI) †	p- value‡
>1 minus ≤1	Pre-announcement	December 2006-July 2008	-0.01 (-0.06-0.04)	1.0000
		August 2008-March 2010	-0.02 (-0.08-0.03)	1.0000
	Announcement	April 2010-November 2011	-0.01 (-0.07-0.04)	1.0000
		January 2013-August 2014	-0.06 (-0.12-0)	0.3523
	Implementation	October 2014-April 2016	-0.05 (-0.11-0.02)	1.0000
		May 2016-November 2017	-0.21 (-0.28--0.13)	<.0001
Compare each period with announcement period (April 2010-November 2011)				
>1	Pre-announcement	December 2006-July 2008	0.33 (0.28-0.38)	<.0001
		August 2008-March 2010	0.09 (0.05-0.14)	0.0015
	Announcement	January 2013-August 2014	0.1 (0.05-0.15)	0.0005
		October 2014-April 2016	0.21 (0.15-0.26)	<.0001
	Implementation	May 2016-November 2017	0.63 (0.57-0.69)	<.0001
	≤1	Pre-announcement	December 2006-July 2008	0.32 (0.28-0.37)
August 2008-March 2010			0.1 (0.06-0.15)	<.0001
Announcement		January 2013-August 2014	0.15 (0.1-0.2)	<.0001
		October 2014-April 2016	0.24 (0.19-0.3)	<.0001
Implementation		May 2016-November 2017	0.83 (0.76-0.89)	<.0001
Compare between hospitals with different nurse-per-bed ratio with announcement period* (April 2010-November 2011)				
>1 minus ≤1	Pre-announcement	December 2006-July 2008	0 (-0.06-0.07)	1.0000
		August 2008-March 2010	-0.01 (-0.08-0.06)	1.0000
	Announcement	January 2013-August 2014	-0.05 (-0.12-0.03)	1.0000
	Implementation	October 2014-April 2016	-0.03 (-0.11-0.04)	1.0000
		May 2016-November 2017	-0.2 (-0.29--0.11)	<.0001

*Definition of abbreviations:* GEE = Generalized Estimating Equation; COPD= Chronic Obstructive Pulmonary Disease; HRRP= Hospital Readmissions Reduction Program; CI= Confidence Interval.

\* GEE model was used to account for the hospital cluster effect among multiple periods.

† Data presented as percentage (CI)

‡ P-value shows the significance of the differences. The p-value was corrected by Bonferroni procedure to account for family-wised error.

§ Announcement period from April 2010 to November 2011 was used as a pivot for comparisons among periods.

We excluded hospitals missing nurse-per-bed data in each period. Table 2 provides detailed number of hospitals with unknown nurse-per-bed data during periods of the HRRP.

**Table E10.** Thirty-day readmission rate at the hospital-level by hospital rating after patients' discharge from COPD hospitalization during periods of the HRRP from December 2006 to November 2017 in the United States.

Compare between hospitals with different rating on each period				
% of patients gave high rating	HRRP Periods		≥70% minus <70% %(CI) †	p-value‡
≥70% minus <70%	Pre-announcement	December 2006-July 2008	-0.12 (-0.23-0)	0.3370
		August 2008-March 2010	-0.18 (-0.26--0.09)	0.0004
	Announcement	April 2010-November 2011	-0.26 (-0.33--0.19)	<.0001
		January 2013-August 2014	-0.18 (-0.25--0.11)	<.0001
	Implementation	October 2014 to April 2016	-0.16 (-0.23--0.08)	0.0002
		May 2016-November 2017	-0.35 (-0.43--0.26)	<.0001
Compare each period with announcement period (April 2010-November 2011)				
≥70%	Pre-announcement	December 2006-July 2008	0.51 (0.4-0.63)	<.0001
		August 2008-March 2010	0.36 (0.28-0.45)	<.0001
	Announcement	January 2013-August 2014	-1.67 (-1.74--1.61)	<.0001
	Implementation	October 2014 to April 2016	-1.43 (-1.5--1.36)	<.0001
		May 2016-November 2017	-1.31 (-1.38--1.24)	<.0001
	<70%	Pre-announcement	December 2006-July 2008	0.37 (0.3-0.43)
August 2008-March 2010			0.28 (0.22-0.33)	<.0001
Announcement		January 2013-August 2014	-1.76 (-1.82--1.7)	<.0001
Implementation		October 2014 to April 2016	-1.53 (-1.6--1.47)	<.0001
		May 2016-November 2017	-1.23 (-1.3--1.15)	<.0001
Compare between hospitals with different rating with announcement period (April 2010-November 2011)				
≥70% minus <70%	Pre-announcement	December 2006-July 2008	0.15 (0.02-0.28)	0.1409
		August 2008-March 2010	0.09 (-0.01-0.19)	0.4652
	Announcement	January 2013-August 2014	0.08 (-0.01-0.18)	0.4117
	Implementation	October 2014 to April 2016	0.11 (0.01-0.2)	0.1493
		May 2016-November 2017	-0.08 (-0.19-0.02)	0.5859

*Definition of abbreviations:* GEE = Generalized Estimating Equation; COPD= Chronic Obstructive Pulmonary Disease; HRRP= Hospital Readmissions Reduction Program; CI= Confidence Interval.

\* GEE model was used to account for the hospital cluster effect among multiple periods.

† Data presented as percentage (CI)

‡ P-value shows the significance of the differences. The p-value was corrected by Bonferroni procedure to account for family-wised error.

§ Announcement period from April 2010 to November 2011 was used as a pivot for comparisons among periods.

Hospitals missing patient rating data in each period were excluded. Table 2 provides the number of hospitals with unknown patient rating data during periods of the HRRP.

**Table E11.** Thirty-day mortality rate at the hospital-level by hospital rating after patients' discharge from COPD hospitalization during periods of the HRRP from December 2006 to November 2017 in the United States.

Compare between hospitals with different rating on each period				
% of patients gave high rating	HRRP Periods		≥70% minus <70% %(CI) †	p-value‡
≥70% minus <70%	Pre-announcement	December 2006-July 2008	-0.04 (-0.11-0.04)	1.0000
		August 2008-March 2010	0.04 (-0.02-0.1)	1.0000
	Announcement	April 2010-November 2011	0.04 (-0.01-0.1)	0.6881
		January 2013-August 2014	-0.03 (-0.09-0.02)	1.0000
	Implementation	October 2014 to April 2016	0.01 (-0.05-0.07)	1.0000
		May 2016-November 2017	-0.07 (-0.15-0.01)	0.4800
Compare each period with announcement period (April 2010-November 2011)				
≥70%	Pre-announcement	December 2006-July 2008	0.27 (0.2-0.35)	<.0001
		August 2008-March 2010	0.11 (0.04-0.17)	0.0151
	Announcement	January 2013-August 2014	0.08 (0.02-0.13)	0.0495
	Implementation	October 2014 to April 2016	0.19 (0.13-0.25)	<.0001
		May 2016-November 2017	0.64 (0.58-0.71)	<.0001
	<70%	Pre-announcement	December 2006-July 2008	0.35 (0.31-0.4)
August 2008-March 2010			0.11 (0.07-0.15)	<.0001
Announcement		January 2013-August 2014	0.16 (0.11-0.21)	<.0001
Implementation		October 2014 to April 2016	0.23 (0.18-0.28)	<.0001
		May 2016-November 2017	0.76 (0.69-0.82)	<.0001
Compare between hospitals with different rating with announcement period (April 2010-November 2011)				
≥70% minus <70%	Pre-announcement	December 2006-July 2008	-0.08 (-0.17-0.01)	0.3858
		August 2008-March 2010	0 (-0.08-0.07)	1.0000
	Announcement	January 2013-August 2014	-0.08 (-0.15-0)	0.1960
	Implementation	October 2014 to April 2016	-0.03 (-0.11-0.05)	1.0000
		May 2016-November 2017	-0.11 (-0.2--0.02)	0.0704

*Definition of abbreviations:* GEE = Generalized Estimating Equation; COPD= Chronic Obstructive Pulmonary Disease; HRRP= Hospital Readmissions Reduction Program; CI= Confidence Interval.

\* GEE model was used to account for the hospital cluster effect among multiple periods.

† Data presented as percentage (CI)

‡ P-value shows the significance of the differences. The p-value was corrected by Bonferroni procedure to account for family-wised error.

§ Announcement period from April 2010 to November 2011 was used as a pivot for comparisons among periods.

Hospitals missing patient rating data in each period were excluded. Table 2 provides the number of hospitals with unknown patient rating data during periods of the HRRP.

**Table E12.** GEE model\* estimated 30-day readmission rate and 30-day mortality rate at the hospital-level after patients' discharge from COPD hospitalization during periods of the HRRP from December 2006 to November 2017 including mortality within a 30-day period from the date of the index admission according to how CMS calculates 30-day mortality rates.

	HRRP Periods		Period minus announcement period*† %(CI) ‡§	p-value ¶
	30-Day Readmission Rate	Pre-announcement	December 2006-July 2008	0.46(0.41-0.5)
August 2008-March 2010			0.32(0.28-0.36)	<.0001
Announcement		January 2013-August 2014.	-1.75(-1.8--1.71)	<.0001
Implementation		October 2014-April 2016	-1.53(-1.58--1.48)	<.0001
		May 2016-November 2017	-1.34(-1.39--1.29)	<.0001
30-Day Mortality Rate		Pre-announcement	December 2006-July 2008	1.11(1.06-1.15)
	August 2008-March 2010		0.31(0.27-0.36)	<.0001
	Announcement	January 2013-August 2014.	0.31(0.25-0.36)	<.0001
	Implementation	October 2014-April 2016	0.36(0.31-0.42)	<.0001
		May 2016-November 2017	0.93(0.88-0.99)	<.0001

*Definition of abbreviations:* GEE = Generalized Estimating Equation; COPD= Chronic Obstructive Pulmonary Disease; HRRP= Hospital Readmissions Reduction Program; CI= Confidence Interval

\* GEE model was used to account for the hospital cluster effect among multiple periods. We compared each periods' mortality rate with announcement period\* (each period minus announcement period\*).

† Announcement period from April 2010 to November 2011 was used as a pivot for comparisons among periods.

‡ Data presented as percentage (CI)

§ Independent risk-adjusted model for 30-day mortality rates that includes in-hospital death according to how CMS calculates 30-day mortality rates (mortality within a 30-day period from the date of the index admission).

¶ P-value shows the significance of the differences. The p-value was corrected by Bonferroni procedure to account for family-wised error.

**Table E13.** GEE model\* estimated 30-day readmission rate and 30-day mortality rate at the hospital-level after patients' discharge from COPD hospitalization comparing rate changes during periods of the HRRP from December 2006 to November 2017 including mortality within a 30-day period from the date of the index admission according to how CMS calculates 30-day mortality rates.

	HRRP Period	Risk adjusted rate %(CI) † ‡	p-value§
30-Day Readmission Rate	Δ (Pre-announcement from <i>December 2006-July 2008</i> to <i>August 2008-March 2010</i> )	-0.13(-0.18--0.09)	<.0001
	Δ (Announcement from <i>January 2013-August 2014</i> to Implementation <i>October 2014-April 2016</i> )	0.22(0.18-0.27)	<.0001
	Δ (Implementation from <i>October 2014-April 2016</i> to <i>May 2016-November 2017</i> )	0.19(0.14-0.24)	<.0001
	Δ (Announcement from <i>January 2013-August 2014</i> to Implementation <i>October 2014-April 2016</i> ) <b>minus</b> Δ(Implementation from <i>October 2014-April 2016</i> to <i>May 2016-November 2017</i> )	-0.03(-0.11-0.04)	1.0000
30-Day Mortality Rate	Δ (Pre-announcement from <i>December 2006-July 2008</i> to <i>August 2008-March 2010</i> )	-0.79(-0.84--0.75)	<.0001
	Δ (Announcement from <i>January 2013-August 2014</i> to Implementation <i>October 2014-April 2016</i> )	0.06(0-0.11)	0.1465
	Δ (Implementation from <i>October 2014-April 2016</i> to <i>May 2016-November 2017</i> )	0.57(0.51-0.63)	<.0001
	Δ (Announcement from <i>January 2013-August 2014</i> to Implementation <i>October 2014-April 2016</i> ) <b>minus</b> Δ(Implementation from <i>October 2014-April 2016</i> to <i>May 2016-November 2017</i> ) <sup>  </sup>	0.51(0.42-0.61)	<.0001

*Definition of abbreviations:* GEE = Generalized Estimating Equation; COPD= Chronic Obstructive Pulmonary Disease; HRRP= Hospital Readmissions Reduction Program; CI= Confidence Interval.

\* GEE model was used to account for the hospital cluster effect among multiple periods.

† Data presented as percentage (CI)

‡ Independent risk-adjusted model for 30-day mortality rates that includes in-hospital death according to how CMS calculates 30-day mortality rates (mortality within a 30-day period from the date of the index admission).

§ P-values are corrected by Bonferroni procedure to account for family-wised error

|| Comparing mortality rate change from announcement to implementation there was a significant 0.51% difference. In other words, mortality rate increased faster in implementation period



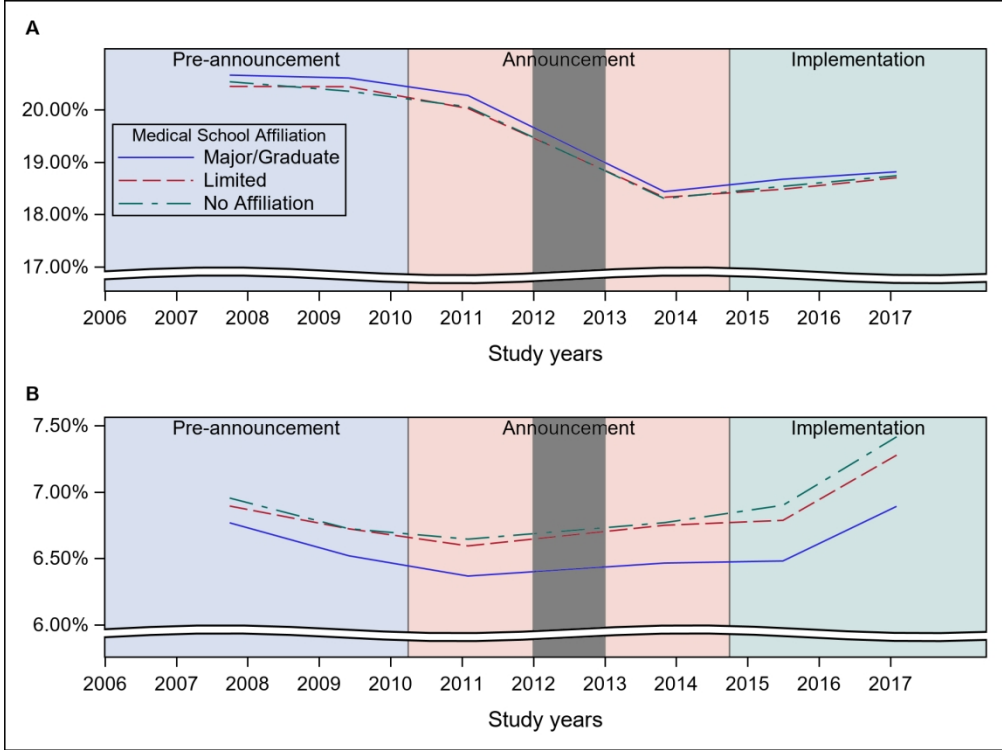


Figure E1. A-B) 30-day Readmission Rate (A) and 30-day Mortality Rate (B) at the Hospital-level by Medical School Affiliation after patients' discharge from COPD hospitalization during periods of the HRRP from December 2006 to November 2017 in the United States. We excluded admissions in the year of 2012 (greyed out area) due to limitations in linking beneficiary identification. HRRP= Hospital Readmissions Reduction Program; COPD= Chronic Obstructive Pulmonary Disease.

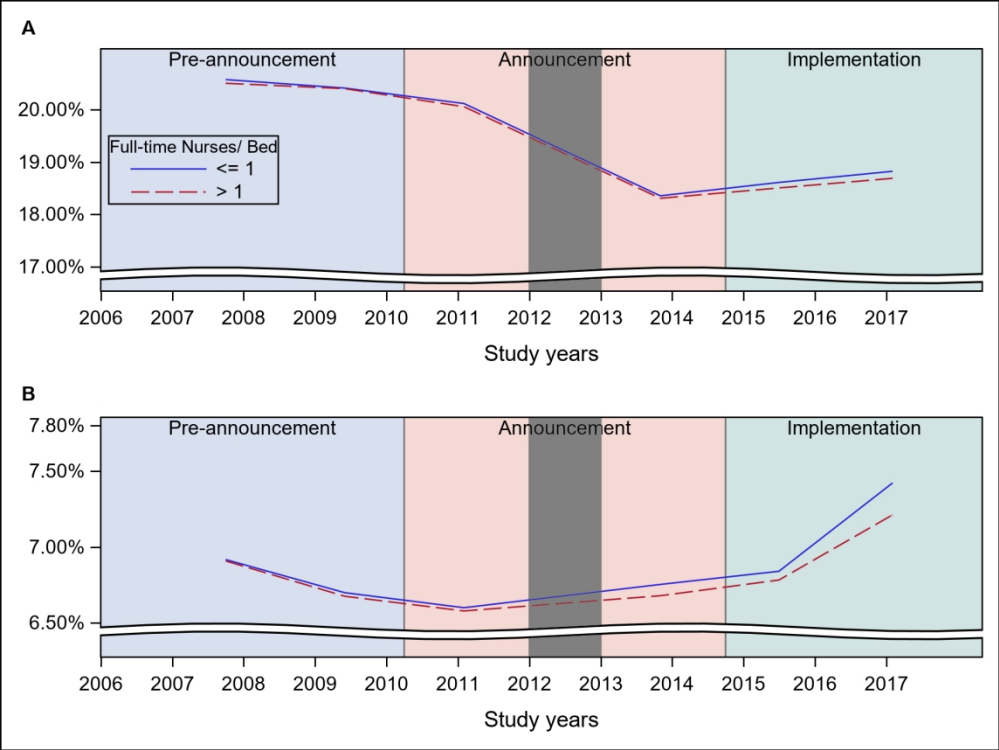


Figure E2. A-B) 30-day Readmission Rate (A) and 30-day Mortality Rate (B) at the Hospital-level by Nurse-per-bed after patients' discharge from COPD hospitalization during periods of the HRRP from December 2006 to November 2017 in the United States. We excluded admissions in the year of 2012 (greyed out area) due to limitations in linking beneficiary identification. HRRP= Hospital Readmissions Reduction Program; COPD= Chronic Obstructive Pulmonary Disease.

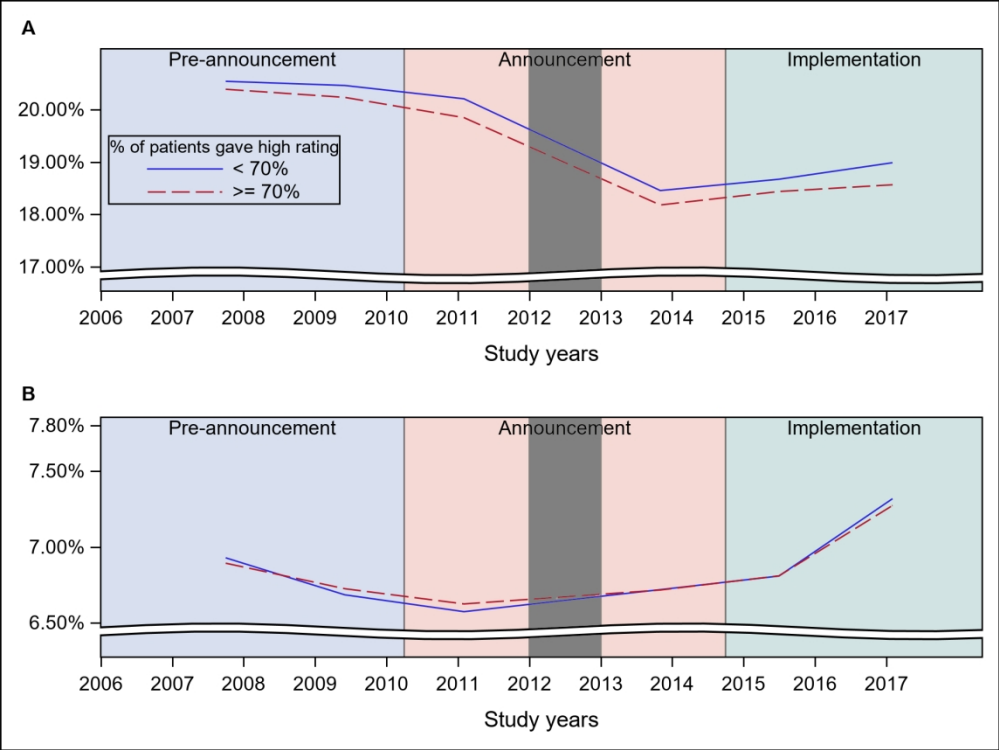


Figure E3. (A-B) 30-day Readmission Rate (A) and 30-day Mortality Rate (B) at the Hospital-level by hospital rating after patients' discharge from COPD hospitalization during periods of the HRRP from December 2006 to November 2017 in the United States. We excluded admissions in the year of 2012 (greyed out area) due to limitations in linking beneficiary identification. HRRP= Hospital Readmissions Reduction Program; COPD= Chronic Obstructive Pulmonary Disease.

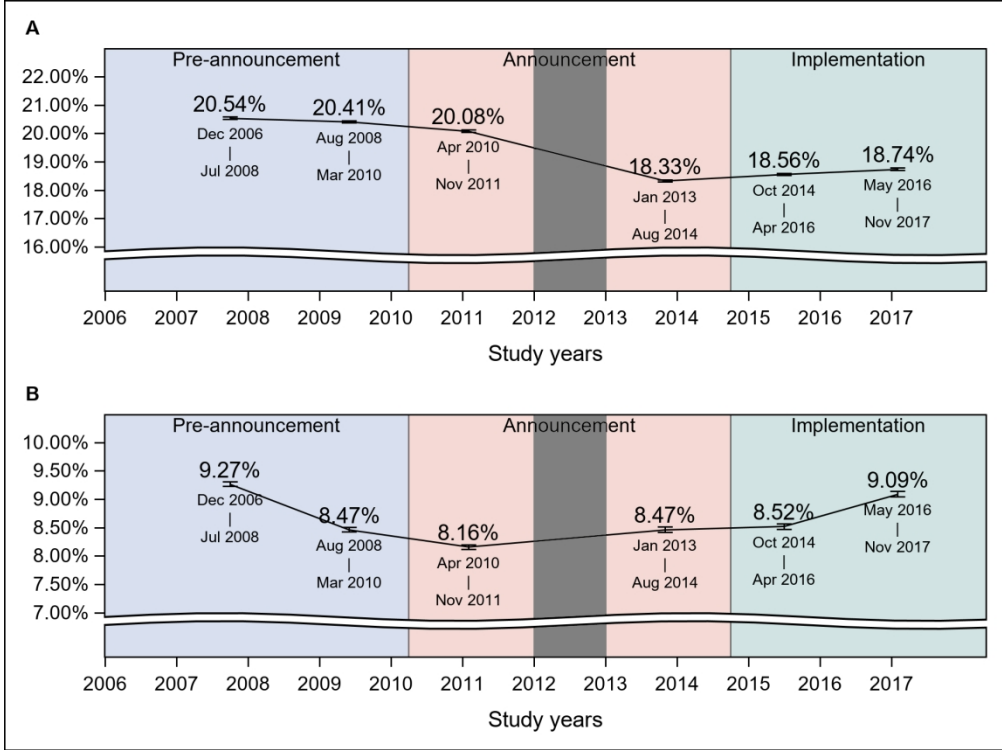


Figure E4. (A-B) 30-day Readmission Rate (A) and 30-day Mortality Rate (B) at the Hospital-level after patients' discharge from COPD hospitalization during periods of the HRRP from December 2006 to November 2017 in the United States. This model includes mortality within a 30-day period from the date of the index admission according to how CMS calculates 30-day mortality rates. We excluded admissions in the year of 2012 (greyed out area) due to limitations in linking beneficiary identification. HRRP= Hospital Readmissions Reduction Program; COPD= Chronic Obstructive Pulmonary Disease; CMS= Centers for Medicare and Medicaid Services.