Early Hospital Readmissions after an Acute Exacerbation of Chronic Obstructive Pulmonary Disease in the Nationwide Readmissions Database

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Abstract

Rationale: Understanding the causes and factors related to readmission for an acute exacerbation of chronic obstructive pulmonary disease (AECOPD) within a nationwide database including all payers and ages can provide valuable input for the development of generalizable readmission reduction strategies.

Objectives: To determine the rates, causes, and predictors for early (3-, 7-, and 30-d) readmission in patients hospitalized with AECOPD in the United States using the Nationwide Readmission Database after the initiation of the Hospital Readmissions Reduction Program, but before its expansion to COPD.

Methods: We conducted an analysis of the Nationwide Readmission Database from 2013 to 2014. Index admissions and readmissions for an AECOPD were defined consistent with Hospital Readmissions Reduction Program guidelines. We investigated the percentage of 30-day readmissions occurring each day after discharge and the most common readmission diagnoses at different time periods after hospitalization. The relationship between predictors (categorized as patient, clinical, and hospital factors) and early readmission were evaluated using a hierarchical two-level logistic model. To examine covariate effects on early-day readmission, predictors for 3-, 7-, and 30-day readmissions were modeled separately.

Results: There were 202,300 30-day readmissions after 1,055,830 index AECOPD admissions, a rate of 19.2%. The highest readmission rates (4.2–5.5%) were within the first 72 hours of discharge, and 58% of readmissions were within the first 15 days. Respiratory-based diseases were the most common reasons for readmission (52.4%), and COPD was the most common diagnosis (28.4%). Readmission diagnoses were similar at different time periods after discharge. Early readmission was associated with patient (Medicaid payer status, lower household income, and higher comorbidity burden) and clinical factors (longer length of stay and discharge to a skilled nursing facility). Predictors did not vary substantially by time of readmission after discharge within the 30-day window.

Conclusions: Thirty-day readmissions after an AECOPD remain a major healthcare burden, and are characterized by a similar spectrum of readmission diagnoses. Predictors associated with readmission include both patient and clinical factors. Development of a COPD-specific risk stratification algorithm based on these factors may be necessary to better predict patients with AECOPD at high risk of early readmission.

Keywords: chronic obstructive pulmonary disease; exacerbations; hospital readmissions; nationwide readmissions database

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Readmission to hospital within 30 days is common, and accounts for over \$17 billion in theoretically avoidable annual Medicare expenditure (1, 2). The Hospital Readmissions Reduction Program (HRRP) was established to target inpatient discharges in the Medicare population to address rising costs and to encourage hospitals to reduce readmissions (3). In the HRRP, hospitals that fail to stay below their expected readmission rates can be penalized up to 3% of total Medicare reimbursement for all discharges. The program initially targeted congestive heart failure, acute myocardial infarction, and pneumonia, but was later expanded in 2015 to target six medical conditions, including acute exacerbation of chronic obstructive pulmonary disease (AECOPD) (3).

Chronic obstructive pulmonary disease (COPD) is an attractive HRRP metric, given that COPD is responsible for almost 700,000 hospitalizations annually, with 1 in 5 patients readmitted within 30 days (1, 4). COPD healthcare costs are estimated at \$50 billion annually in the United States, and hospital readmissions alone account for over \$15 billion (5–7). Despite the potential benefits of a readmission program for AECOPD, the COPD population faces a number of unique challenges: there is no clear link between quality of care and 30-day hospital readmissions; no AECOPD interventions to date significantly reduce readmission rates; and safety-net hospitals might be unfairly penalized, thereby worsening health disparities (8–12). Identifying drivers of early hospital readmission for high-risk patients would be useful to optimize readmission reduction programs, as it may allow key stakeholders to risk-stratify patients and apply necessary resources to enhance patient-centered care. Recent studies have shown a number of factors associated with an increased risk of early readmission; however, most of this work was done before HRRP implementation, focused on specific population groups, or was confined to geographically limited health care systems (13–17). Furthermore, analysis of Medicare claims studies may not be generalizable to patients younger than 65 years of age, and private claims data may not extend to patients on Medicare or Medicaid (13, 18). To design generalizable COPD readmission reduction strategies, it would be important to understand causes and risk factors using a nationwide database that includes all payers and ages.

As hospitals implement interventions to reduce COPD readmissions, it is crucial to recognize the causes and reasons for early readmission and which patient (particularly socioeconomic and comorbidity data), clinical, and hospital factors raise readmission risk. Therefore, the objectives of this study were to evaluate the rates, causes, and predictors for early readmission in patients hospitalized with AECOPD in the United States using the Nationwide Readmission Database (NRD). This study is novel in the following ways: 1) the NRD is a large-scale administrative database designed specifically to support analyses of national readmissions for all ages and payers; 2) index admissions and readmissions for an AECOPD were defined consistent with HRRP measures; and 3) the study time period was after HRRP initiation, but before its expansion to COPD.

Methods

Data Source

We used data from the 2013 and 2014 NRD developed by the Agency for Healthcare Research and Quality for the Healthcare Cost and Utilization Project (19). At time of analysis, NRD data were only available over this time period. The NRD is drawn from the Healthcare Cost and Utilization Project State Inpatient Databases, which contain reliable, verified patient linkage numbers to track a person across within-state hospitals. The NRD is limited to data from community hospitals, including academic facilities (not rehabilitation or long-term acute care facilities). The NRD contains records for persons who are considered “inpatient,” and does not include observation services or those not admitted to the hospital. The NRD compiled approximately 15 million raw discharges in 2013 and 2014, corresponding to approximately 35 million weighted discharges from 22 states and representing 49% of U.S. discharges for each year. Due to the complex NRD survey design, sample weights were applied to raw data to generate national estimates. The University at Buffalo Institutional Review Board exempted this study from review, as it uses publicly available, anonymized data.

Study Sample

All adult patients (aged ≥ 40 yr) with an *International Classification of Disease, Ninth Revision, Clinical Modification* (ICD-9-CM) code for AECOPD were included in the

analysis. The ICD-9-CM codes were chosen based on those published by the Centers for Medicare and Medicaid Services (CMS) for the HRRP for assessment of all-cause readmissions for an AECOPD (20). These included a primary discharge diagnosis code of COPD (ICD-9-CM codes 491.21, 491.22, 491.8, 491.9, 492.8, 493.20, 493.21, 493.22, and 496) or a primary diagnosis of respiratory failure (ICD-9-CM codes 518.81, 518.82, 518.84, and 799.1) and a secondary diagnosis of AECOPD (ICD-9-CM codes 491.21, 491.22, 493.21, and 493.22). We limited our index hospitalizations to January 1 to November 30, 2013 and 2014, to capture all 30-day readmissions. We excluded patients if they died during the index hospitalization, the readmission visit was elective, they were discharged against medical advice, the length of stay variable was missing, or if they were residents of a different state ($n = 141,671$). Within the NRD, persons are identified by State-specific linkage numbers and, therefore, cannot be tracked across states.

Covariates

Predictor variables were classified as demographics, pre-existing comorbidities, and clinical and hospital characteristics. Demographic and socioeconomic status variables were age, sex, insurance status, and household income. Age was stratified into groups of 40–64 and 65 years or older. Insurance status was categorized as Medicare, Medicaid, private insurance, self-pay, or “other” (including no charge). Income levels were based on the estimated median household income of residents in the patient’s zip code and were divided into \$1–\$37,999, \$38,000–\$47,999, \$48,000–\$63,999, and \$64,000 or greater. We further examined comorbidities prevalent in this population based on existing literature, including congestive heart failure, alcohol abuse, depression, diabetes mellitus, renal failure, and obesity (21, 22). Pre-existing comorbidities were assessed individually and as overall comorbidity burden using the methodology provided by the Agency for Healthcare Research and Quality (23).

Clinical and hospital variables included post-acute care disposition (home, skilled nursing facility [SNF], and home health care), hospital size (small, medium, or large based on bed size and hospital location, with larger cut-offs for hospitals in urban locations), ownership (government [public], private [not-for-profit], and private

[investor-owned]), location (large metropolitan area [≥ 1 million residents], small metropolitan [< 1 million residents], and “other” [including micropolitan and nonurban areas]), and teaching status (metropolitan nonteaching, metropolitan teaching, and nonmetropolitan). Length of stay during the index hospitalization was categorized as less than 2, 2–5, and greater than 5 days. Due to the positive skew of length of stay, we categorized the variable into tertiles based on its distribution.

Outcomes

Readmission timing. We identified the percentage of 30-day readmissions occurring on each day (Days 1–30) after discharge. We used definitions consistent with the CMS HRRP measures to identify all readmissions from any cause occurring within 30 days of hospitalization (20). Briefly, the CMS measures only define the first readmission within 30 days of discharge as a 30-day readmission. Additional readmissions within the 30-day period are not counted as 30-day readmissions or index hospitalizations for the same condition. After 30 days from discharge, hospitalizations are counted as index admissions if they meet inclusion criteria. We determined if readmission changes were uniform across two age groups: younger adults (40–64 yr) and older adults (≥ 65 yr).

Readmission diagnoses by time after discharge. We identified the 10 most common reasons for readmission based on Clinical Classification Software (CCS; Healthcare Cost and Utilization Project [HCUP]) (24). We also identified the most common readmission diagnoses during cumulative periods (Days 1–3, 1–7, 1–15, and 1–30) and consecutive periods after discharge (Days 1–3, 4–7, 8–15, and 16–30). These periods were chosen because cumulative periods after discharge may occur before outpatient follow-up and be of importance to discharging hospitals, whereas consecutive periods may coincide with outpatient visits and be of importance to ambulatory care providers (25).

Predictors of hospital readmission. We examined whether patient-, clinical-, and hospital-specific factors were associated with early readmissions at 3, 7, and 30 days.

Statistical Analyses

Summary statistics for readmission timing by day after discharge (Days 1–30),

readmission diagnoses by CCS codes, and readmission diagnoses for cumulative and consecutive periods were calculated. Chi-square tests and Student's *t* tests were used to compare proportions and continuous variables, respectively. Three multivariable hierarchical logistic regression models were built to determine the independent predictors for early readmission. Hierarchical two-level logistic models with hospital identification as a random effect were used to account for clustering of observations within hospitals. To examine the effect of covariates on early readmission, we modeled 3-, 7-, and 30-day readmissions separately. Each model included patient demographics (age, sex, insurance type, and median household income), pre-existing comorbidities (individual comorbidities and comorbidity burden), and clinical (post-acute care disposition and length of stay) and hospital characteristics (hospital bed size, ownership, and teaching status). Odds ratios (ORs) and 95% confidence intervals (CIs) were estimated, and each estimate was adjusted for all other variables in the model. All analyses were performed using SAS version 9.4 (SAS Institute), and all hypothesis testing was two sided, with significance set as *P* less than or equal to 0.05.

Results

There were 202,300 30-day readmissions after 1,055,830 hospitalizations for an AECOPD (19.2%; Table 1). The percentages of index admissions readmitted were similar in 2013 and 2014 (19.1% and 19.2%, respectively). Individuals aged 65 years or greater accounted for 642,004 index AECOPD admissions over the study period

and 124,941 readmissions (20%). Those aged 40–64 years had a slightly lower frequency and rate of 30-day readmissions at 18% (77,359 readmissions).

The median (interquartile range [IQR]) age of the cohort was 68 (58–77) years, and 59% were female (Table 2). Most patients had Medicare insurance status (70%) followed by Medicaid (13%). The median length of stay was 2.9 (1.7–4.8) days, and 68% of patients were discharged home after their index hospitalization. Index admission patients had a median of 6.2 (4.2–8.4) chronic conditions, with common comorbidities of hypertension (68%), diabetes (32%), and fluid and electrolyte disorders (26%) (see Table E1 in the data supplement).

Readmission Hospitalizations, Diagnoses, and Costs

Of all 30-day readmissions, 14.4% of AECOPD readmissions occurred within 3 days after discharge (Figure 1). Approximately 30% of readmissions were within the first 7 days, and 58% were within the first 15 days. Ranked reasons for readmission for the 10 most common CCS codes are presented in Table 3. The most common reasons were: 1) COPD and bronchiectasis (28.4%); 2) respiratory failure (9.5%); 3) pneumonia (7.6%); 4) asthma (7.0%); and 5) congestive heart failure (5.8) (Table 3). Collectively, respiratory diseases, including COPD, respiratory failure, pneumonia, and asthma, comprised 52.4% of readmissions. Cardiovascular disease (9.4%), septicemia (5.7%), and renal disease (1.5%) accounted for the remaining readmissions.

Both age subgroups had similar readmission diagnoses (Table 3). The most common reasons for readmissions among

Table 1. Frequency of index acute exacerbation chronic obstructive pulmonary disease admissions and readmissions stratified by age group

Year and Age Groups	Total AECOPD Index Admissions	No. of 30-Day Readmissions	Index Admissions Readmitted (%)
Total	1,055,830	202,300	19.2
2013	547,291	104,478	19.1
40–64 yr	210,118	39,029	18.6
≥65 yr	337,173	65,449	19.4
2014	508,539	97,822	19.2
40–64 yr	203,708	38,330	18.8
≥65 yr	304,831	59,492	19.5

Definition of abbreviation: AECOPD = acute exacerbation of chronic obstructive pulmonary disease.

Table 2. Baseline clinical and demographic characteristics of index hospitalizations for patients with an acute exacerbation of chronic obstructive pulmonary disease

Characteristics	No. (%) (n = 1,055,830)
Age, yr, median (IQR)	68 (58–77)
Age groups, yr	
40–49	64,281 (6.1)
50–64	349,546 (33)
65–74	325,732 (30)
≥75	316,271 (30)
Sex	
Male	437,812 (41)
Female	618,018 (59)
Insurance type	
Medicare	742,617 (70)
Medicaid	133,399 (13)
Private	112,984 (11)
Self-pay	34,856 (3.3)
Other	31,012 (2.9)
Discharge location	
Home	720,933 (68)
Home health	196,682 (19)
SNF/other*	137,948 (13)
Median household income	
≥\$64,000	156,889 (15)
\$48,000–\$63,999	215,307 (20)
\$38,000–\$47,999	298,844 (29)
≤\$37,999	369,959 (36)
No. of comorbidities, median (IQR)	6.2 (4.2, 8.4)
No. of comorbidities, n (%)	
≤5	365,267 (35)
>5 to ≤7	275,695 (26)
>7 to ≤9	210,091 (20)
>9	204,777 (19)

Definition of abbreviations: IQR = interquartile range; SNF = skilled nursing facility.

*Other includes transfers to immediate care, another type of facility, or discharged alive and destination unknown.

patients 65 years or older included COPD and bronchiectasis (27%), pneumonia (8.6%), respiratory failure (8.6%), congestive heart failure (6.8%), and septicemia (6.6%). A higher percentage of 40–64 year olds were readmitted for respiratory disease compared with those aged 65 years or older (59.1% vs. 48.3%). The overall diagnosis pattern was similar in both consecutive and cumulative periods of discharge (Figures E1 and E2). Respiratory diseases, including COPD, respiratory failure, pneumonia, and asthma, were the four most common readmission diagnoses, regardless of time to follow-up, and changed only slightly within the 30-day period.

Among patients with an AECOPD who were readmitted within 30 days, the median total charge for the first readmission was \$27,349 (IQR = \$15,605–\$49,962). Readmission charges were 21% higher than the median charges of the index hospitalization (median = \$22,535, IQR = \$13,547–\$38,360). When aggregated for all patients with AECOPD in the NRD over 2 years, the total charges attributable to the first readmission within 30 days were over \$9 billion.

Predictors Associated with Early Readmission

Univariate index predictors for 3-, 7-, and 30-day readmissions are shown in Table E2. In multivariable analysis, factors associated with an increased odds of 3-day readmission included Medicaid payer status (compared with Medicare, adjusted OR [aOR] = 1.09, 95% CI = 1.03–1.16) and a lower median household income (\$38,000–\$47,999, aOR = 1.09, 95% CI = 1.03–1.15; ≤\$37,999, aOR = 1.11, 95% CI = 1.04–1.17; Table 4). Comorbidities with the highest odds of readmission included patients with renal failure (aOR = 1.16, 95% CI = 1.10–1.22) and alcohol abuse (aOR = 1.14, 95% CI = 1.06–1.24). Higher comorbidity burden was also associated with an increased odds of readmission ($P < 0.0001$).

When evaluating clinical and hospital factors (Table 4), patients with a longer length of index hospitalization (>5 d vs. ≤2 d, aOR = 1.23, 95% CI = 1.17–1.29) were more likely to be readmitted within 3 days. Post-acute care involving an SNF or home healthcare was also associated with an increased odds of readmission (SNF, aOR = 1.26, 95% CI = 1.19–1.33; home health care, aOR = 1.26, 95% CI = 1.20–1.32).

Predictors of 7- and 30-day readmissions were similar to 3-day readmissions (Table 4). Being in the older age group was associated with a lower odds of 30-day readmission (65–74 yr, aOR = 0.88, 95% CI = 0.85–0.91; ≥75 yr, aOR = 0.78, 95% CI = 0.75–0.81). Medicaid payer status, lower household income, higher comorbidity burden, length of stay, and discharge location were all associated with higher odds of 7- and 30-day readmission.

Discussion

This study used a nationwide readmission database to provide national estimates

of readmission after an AECOPD under the HRRP COPD methodology. Nearly one-fifth of patients with AECOPD were readmitted within 30 days, with approximately one-third occurring within 1 week and the highest daily rates of readmission (4.2–5.5%) within the first 72 hours. Causes of readmission after hospitalization for an AECOPD were primarily respiratory in nature. Furthermore, a number of patient and clinical factors were associated with readmission, including socioeconomic markers, higher comorbidity burden, and post-acute care disposition.

Our 30-day readmission rate of 19.1% is consistent with previous studies (1, 4, 26). Shah and colleagues (13) recently examined AECOPD-related hospitalizations and readmissions among Medicare beneficiaries from 2006 to 2010 and reported a 30-day readmission rate of 20.2%. Although this study enrolled Medicare patients in seven states, our sample included all patients 40 years or older and all payers, and so represents a more comprehensive representation of the U.S. COPD population. Furthermore, other studies on COPD readmissions evaluated samples from employer-sponsored health insurance, which may further limit their generalizability (14, 18). COPD treatment is complex, and the approaches used to reduce COPD readmissions are unclear. A systematic review of randomized, controlled trials implementing AECOPD rehospitalization reduction interventions failed to find clinical trials targeting a 30-day readmission outcome; rather, these studies had a primary outcome of rehospitalization at 6 or 12 months (9). The included trials tested different interventions, and only two of the five studies demonstrated a significant decrease in rehospitalizations in the intervention group. Given the lack of evidence to recommend a specific intervention, a large database such as the NRD may be used to integrate patient, clinical, and hospital factors to develop a real-time predictive model to identify patients with COPD at high risk of early readmission. To date, there are no rigorously tested, COPD-specific algorithms to predict risk of 30-day readmission. The next step would be to develop and validate a risk stratification algorithm based on these factors to better predict patients with AECOPD at high risk of early readmission. Patients with COPD have a unique set

Figure 1. Frequency and percent of readmissions on each day after discharge after a hospitalization for an acute exacerbation of chronic obstructive pulmonary disease. The line indicates the percentage of patients readmitted and the bars indicate the frequency of readmissions. Index admissions: 1,055,830; total 30-day readmissions: 202,300.

of complications that are important in identifying high-risk patients. A predictive model incorporating these factors at real time during a patient's index admission may allow providers and hospitals to risk stratify patients and apply necessary resources to enhance patient-focused care. Such a model can then be incorporated into COPD-specific readmission reduction programs.

Consistent with other studies, the majority of readmissions occurred within 14 days, with the highest rates in the first 3 days (13, 25), representing a diverse spectrum of readmission diagnoses. Furthermore, there were no major differences in readmission diagnoses grouped by time period after discharge. Provided the majority of readmissions are in the short term and primarily respiratory in nature, a multifaceted approach could be considered to successfully transition patients back into the community (27). Comprehensive care management and bundled care programs, including multiple providers and a coordinated team to provide comprehensive services to patients with COPD, have been evaluated, but results are mixed (28–30). A recent study by Bhatt and colleagues (31) evaluated a comprehensive program

that provided multidisciplinary care across the hospital-to-home transition. The intervention showed no reduction in 30-day or 90-day readmission rates or cost savings, although the study was underpowered to detect a significant difference in readmission rates. Jennings and colleagues (32) performed a single-center randomized trial of patients with AECOPD implementing a multicomponent intervention, including smoking cessation, screening for gastroesophageal reflux disease, and depression or anxiety, COPD education, and postdischarge communication. Overall, the authors found no difference in readmission rates between patients receiving a bundled intervention and standard care.

We identified a number of patient-level factors associated with an increased risk of early readmission. One was socioeconomic status, which has not been extensively studied. Medicaid beneficiaries and those in the lowest two household income quartiles were more likely to be readmitted. This is of concern, because Medicaid beneficiaries are more likely to have barriers to primary care than those with private insurance, which can lead to higher emergency department utilization (33). These barriers associated

with lower socioeconomic characteristics may represent unique challenges beyond the control of hospitals and independently increase the likelihood of readmission. Furthermore, patients with COPD are more likely to have less-than-adequate health literacy and to misuse respiratory inhalers, which further complicates readmission reduction strategies (34). From a policy perspective, the readmission equation, as calculated by CMS for HRRP, does not adjust for socioeconomic factors, raising the concern that financial penalties may worsen health disparities by unfairly penalizing safety-net hospitals. During the first year of the HRRP program, safety-net hospitals had a higher adjusted odds of being penalized versus non-safety net facilities (35). Because the penalty associated with the HRRP increased to 3% for fiscal year 2015, this may create substantial financial shortfalls for hospitals operating on low profit margins, such as safety net facilities.

Patients with AECOPD had a high comorbidity burden independently associated with readmission. Comorbidities, including cardiovascular disease, diabetes, and depression, increase the complexity of COPD management (36, 37). We found

Table 3. Ranked 30-day readmissions diagnoses by patient age and clinical classification software categories among those hospitalized with an acute exacerbation of chronic obstructive pulmonary disease

Rank	30-Day Readmissions after COPD Exacerbation Hospitalization		30-d Readmissions after COPD Exacerbation Hospitalization (40–64 Yr)		30-Day Readmissions after COPD Exacerbation Hospitalization (≥65 Yr)	
	Diagnosis by CCS	Percentage of Readmissions	Diagnosis by CCS	Percentage of Readmissions	Diagnosis by CCS	Percentage of Readmissions
1	COPD and bronchiectasis	28.36	COPD and bronchiectasis	31.01	COPD and bronchiectasis	26.72
2	Respiratory failure	9.47	Respiratory failure	11.03	Pneumonia	8.59
3	Pneumonia	7.64	Asthma	10.94	Respiratory failure	8.57
4	Asthma	6.97	Pneumonia	6.11	Congestive heart failure	6.81
5	Congestive heart failure	5.80	Septicemia	4.34	Septicemia	6.58
6	Septicemia	5.72	Congestive heart failure	4.16	Asthma	4.45
7	Cardiac dysrhythmias	2.44	Cardiac dysrhythmias	1.58	Cardiac dysrhythmias	2.97
8	Acute and unspecified renal failure	1.52	Nonspecific chest pain	1.49	Acute and unspecified renal failure	1.85
9	Acute myocardial infarction	1.12	Mood disorders	1.30	Aspiration pneumonia	1.45
10	Fluid and electrolyte disorders	1.10	Skin and subcutaneous tissue infections	1.27	Gastrointestinal hemorrhage	1.40

Definition of abbreviations: CCS = Clinical Classification Software; COPD = chronic obstructive pulmonary disease.

that congestive heart failure is a common comorbidity, and readmission diagnosis among patients with COPD and congestive heart failure has been shown to be the most common readmission diagnosis after respiratory-based diseases (1, 13). Depression is also common in patients with COPD, and has been shown to be associated with an increased risk of both all-cause and COPD-specific early readmissions (38, 39). Given that multiple comorbidities are typical in patients with COPD, a multidisciplinary approach may help to prevent readmissions.

Several clinical factors played a role in COPD readmissions, including length of index hospitalization and post-acute care disposition. A longer index hospitalization has previously been shown to be associated with a higher risk of readmission (13, 18). Although length of stay may not in itself be modifiable, it can be used to identify patients at higher risk of early readmission and who might, therefore, benefit from closer follow-up during transition from acute care. Post-acute care discharge to an SNF or with home healthcare was associated with higher odds of readmission, similar to Shah and colleagues (13) for 30-day readmission. Patients discharged with additional care tend to be more unwell than those discharged home. However, the quality of care delivered at SNFs may also merit further investigation.

It is important to note that the data included in this analysis were from after the implementation of HRRP for congestive heart failure, acute myocardial infarction, and pneumonia, but before its expansion to COPD. Programs such as Project RED (Re-Engineered Discharge) have been successful at reducing readmissions; however, COPD-specific programs have not had similar success. Although HRRP interventions for other diagnoses may have been introduced during this time, their impact on COPD readmissions is most likely minimal. It is currently unclear what combination of interventions is necessary to reduce readmissions among patients with COPD exacerbations. Therefore, it will be necessary to re-evaluate COPD readmission trends as additional data become available and hospitals respond to the HRRP standards.

Our study is limited by the fact that we relied on ICD-9-CM codes to classify index AECOPD hospitalizations. The CMS HRRP algorithm to define AECOPD by discharge ICD-9-CM codes has yet to be tested or

Table 4. Independent predictors associated with 3-, 7-, and 30-day readmissions after hospitalization for an acute exacerbation of chronic obstructive pulmonary disease*

Characteristic	3-Day Readmission		7-Day Readmission		30-Day Readmission	
	aOR (95% CI)	P Value	aOR (95% CI)	P Value	aOR (95% CI)	P Value
Patient factors						
Age, yr						
40–49	1 (Reference)		1 (Reference)		1 (Reference)	
50–64	1.01 (0.93–1.10)	0.82	0.98 (0.92–1.04)	0.45	0.98 (0.95–1.02)	0.26
65–74	0.94 (0.85–1.02)	0.14	0.89 (0.84–0.95)	<0.001	0.88 (0.85–0.91)	<0.0001
≥75	0.90 (0.82–0.99)	0.03	0.84 (0.79–0.90)	<0.0001	0.78 (0.75–0.81)	<0.0001
Sex						
Male	1 (Reference)		1 (Reference)		1 (Reference)	
Female	0.86 (0.83–0.89)	<0.0001	0.86 (0.84–0.89)	<0.0001	0.87 (0.85–0.88)	<0.0001
Insurance type						
Medicare	1 (Reference)		1 (Reference)		1 (Reference)	
Medicaid	1.09 (1.03–1.16)	0.004	1.10 (1.05–1.15)	<0.0001	1.15 (1.12–1.18)	<0.0001
Private	0.79 (0.73–0.84)	<0.0001	0.75 (0.71–0.79)	<0.0001	0.70 (0.68–0.72)	<0.0001
Self-pay	0.70 (0.62–0.80)	<0.0001	0.65 (0.59–0.72)	<0.0001	0.61 (0.58–0.64)	<0.0001
Others	0.81 (0.72–0.91)	<0.001	0.87 (0.81–0.95)	<0.001	0.80 (0.76–0.84)	<0.0001
Median household income						
≥\$64,000	1 (Reference)		1 (Reference)		1 (Reference)	
\$48,000–\$63,999	1.04 (0.98–1.10)	0.26	1.05 (1.01–1.10)	0.02	1.02 (0.99–1.05)	0.13
\$38,000–\$47,999	1.09 (1.03–1.15)	0.005	1.09 (1.05–1.13)	<0.0001	1.05 (1.03–1.08)	<0.0001
≤\$37,999	1.11 (1.04–1.17)	<0.01	1.11 (1.06–1.15)	<0.0001	1.08 (1.05–1.10)	<0.0001
Comorbidities						
Alcohol abuse	1.14 (1.06–1.24)	<0.01	1.17 (1.10–1.23)	<0.0001	1.13 (1.09–1.16)	<0.0001
Congestive heart failure	1.13 (1.08–1.18)	<0.0001	1.17 (1.14–1.21)	<0.0001	1.28 (1.26–1.31)	<0.0001
Depression	0.98 (0.93–1.03)	0.44	0.98 (0.94–1.01)	0.17	1.00 (0.98–1.02)	0.77
Diabetes mellitus	1.01 (0.97–1.05)	0.59	1.02 (0.99–1.05)	0.14	1.04 (1.02–1.06)	<0.0001
Renal failure	1.16 (1.10–1.22)	<0.0001	1.18 (1.14–1.22)	<0.0001	1.19 (1.17–1.22)	<0.0001
Obesity	0.83 (0.79–0.87)	<0.0001	0.83 (0.80–0.85)	<0.0001	0.87 (0.85–0.89)	<0.0001
No. of comorbidities						
≤5	1 (Reference)		1 (Reference)		1 (Reference)	
>5 to ≤7	1.18 (1.12–1.24)	<0.0001	1.14 (1.10–1.18)	<0.0001	1.19 (1.16–1.21)	<0.0001
>7 to ≤9	1.25 (1.19–1.32)	<0.0001	1.25 (1.20–1.30)	<0.0001	1.30 (1.27–1.33)	<0.0001
>9	1.38 (1.30–1.47)	<0.0001	1.39 (1.33–1.45)	<0.0001	1.46 (1.43–1.50)	<0.0001
Hospital and clinical factors						
Bed size of hospital						
Large	1 (Reference)		1 (Reference)		1 (Reference)	
Medium	1.04 (0.99–1.08)	0.06	1.01 (0.98–1.03)	0.71	0.95 (0.93–0.97)	<0.0001
Small	1.04 (0.98–1.09)	0.19	0.98 (0.94–1.01)	0.23	0.99 (0.97–1.01)	0.15
Hospital ownership						
Government, nonfederal	1 (Reference)		1 (Reference)		1 (Reference)	
Private, not for profit	0.94 (0.89–0.99)	0.02	0.96 (0.93–0.99)	0.04	0.97 (0.95–0.99)	0.02
Private, investor owned	1.06 (0.99–1.13)	0.055	1.06 (1.01–1.10)	0.02	1.03 (1.00, 1.06)	0.02
Teaching status of hospital						
Metropolitan, nonteaching	1 (Reference)		1 (Reference)		1 (Reference)	
Metropolitan teaching	0.98 (0.94–1.02)	0.23	1.01 (0.98–1.03)	0.74	1.03 (1.01–1.04)	<0.0001
Nonmetropolitan	0.91 (0.86–0.97)	0.002	0.92 (0.88–0.96)	<0.001	0.89 (0.87–0.91)	<0.0001
Discharge location						
Home	1 (Reference)		1 (Reference)		1 (Reference)	
Home healthcare	1.26 (1.20–1.32)	<0.0001	1.31 (1.27–1.35)	<0.0001	1.32 (1.30–1.35)	<0.0001
SNF/other	1.26 (1.19–1.33)	<0.0001	1.20 (1.16–1.25)	<0.0001	1.28 (1.25–1.31)	<0.0001
Length of stay at index hospitalization, d						
≤2	1 (Reference)		1 (Reference)		1 (Reference)	
>2 to ≤5	0.94 (0.90–0.98)	0.004	0.99 (0.97–1.03)	0.83	1.06 (1.04–1.08)	<0.0001
>5	1.23 (1.17–1.29)	<0.0001	1.35 (1.30–1.40)	<0.0001	1.32 (1.29–1.34)	<0.0001

Definition of abbreviations: aOR = adjusted odds ratio; CI = confidence interval; SNF = skilled nursing facility.

*Each estimate is adjusted for all other variables in the model.

validated. Previous work testing several coding algorithms similar to the CMS HRRP methodology against chart review found that coding underestimated AECOPD. The sensitivities of the different

ICD-9-CM algorithms were low and varied (12–25%), with positive predictive values as low as 81% (40). Furthermore, we used this methodology to identify index hospitalizations for younger patients with

AECOPD not included in the HRRP. However, because this methodology is used by CMS to identify AECOPD admissions, we thought it prudent to apply it to the entire study to provide national readmission

estimates. Our study also relied on accurate coding of administrative claims data, which may not be as reliable as a medical record review. The lack of an acceptable biomarker to objectively diagnose COPD exacerbations adds to the complexity of accurately coding hospitalizations, given that COPD symptoms overlap with many other diseases. Due to a limitation in the NRD, we excluded patients who were residents of different states. Persons are identified and tracked in the NRD by state-specific linkage numbers; therefore, a person readmitted between two different states cannot be tracked between states. This

limitation in the NRD may cause readmissions rates to be artificially low; an analysis of Medicare claims data showed a 1.9% increase in COPD-specific readmission rates when patients were followed across states (19). Furthermore, we were not able to track observation services, because these types of admissions are not included in the NRD. Future studies should use claims data to evaluate the impact of HRRP programs on noninpatient services.

Conclusions

Early readmission for AECOPD remains a burden to the healthcare system,

with the majority readmitted for respiratory-based diagnoses. Multiple patient and clinical factors were associated with readmission, including those related to low socioeconomic status and post-acute care discharge to an SNF. Further work is needed to develop a risk stratification algorithm based on these factors to better predict patients with AECOPD at high risk of early readmission during the index hospitalization. ■

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