Predictors of Early Readmission among Patients 40 to 64 Years of Age Hospitalized for Chronic Obstructive Pulmonary Disease

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Abstract

Rationale: Various causes can contribute to the high rates of readmission among patients hospitalized with chronic obstructive pulmonary disease (COPD).

Objectives: To determine the frequency and predictors of early readmission among patients aged 40–64 years, hospitalized with COPD.

Methods: In a retrospective cohort study, using a large national commercial insurance database, we obtained the clinical information within 12 months of the index hospitalization and 30 days after discharge.

Measurements and Main Results: Primary outcome was early readmission, defined as hospitalization within 30 days of discharge. We categorized predictor variables as patient, provider, and system factors, and compared these variables between patients readmitted and those not readmitted. Logistic regression was used for multivariable analysis. Of 8,263 patients who met the inclusion criteria, 741 (8.9%) had early readmission. Multivariable analysis showed patient factors (male, history of heart failure, lung cancer, osteoporosis, and depression), provider factors (no prior prescription of statin within 12 mo of the index hospitalization and no prescription of short-acting bronchodilator, oral steroid and antibiotic on discharge), and system factors (length of stay, <2 or >5 d and lack of follow-up visit after discharge) were associated with early readmission among patients hospitalized with COPD. The C-statistic of the model including patient characteristics was 0.677 (95% confidence interval, 0.656–0.697), which was improved to 0.717 (95% confidence interval, 0.702–0.732) after addition of provider- and system-based factors.

Conclusions: One of 11 patients hospitalized with COPD is readmitted within 30 days of discharge. Provider and system factors are important modifiable risk factors of early readmission.

Keywords: hospital readmission; chronic obstructive pulmonary disease; follow-up visit

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In 2009, the Centers for Medicare and Medicaid Services began to publicly report 30-day risk-standardized readmission rates for pneumonia, congestive heart failure (CHF) and acute myocardial infarction, as a quality performance measure (1–3). Although some readmissions may be unavoidable, reducing hospital readmissions has been an objective of the Affordable Care Act and Accountable Care Organizations. The readmission reduction program seeks to reduce unnecessary readmissions of patients. One in five Medicare beneficiaries is hospitalized within 30 days of hospital discharge (4), at a cost of more than $15 billion annually (4, 5).

High rates of hospital readmissions and unexplained variation in those rates may indicate problems in delivery of care, transitions of care, or outpatient management after discharge. Improving the quality of care during care transitions at the time of hospital discharge may result in fewer hospital readmissions and associated costs (6, 7). In 2012, the Centers for Medicare and Medicaid Services started to reduce Medicare payments to hospitals with high readmission rates for patients admitted with CHF, myocardial infarction, and pneumonia (8). Starting from fiscal year 2015, this list will also

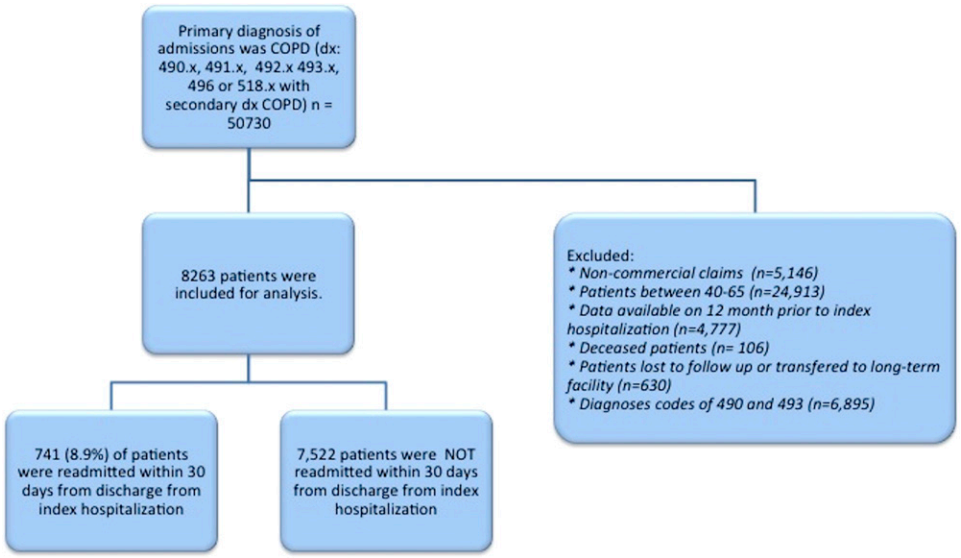

Figure 1. Establishment of a cohort of patients 40–64 years of age and hospitalized between 2009 and 2011 with a primary diagnosis of chronic obstructive pulmonary disease (COPD). dx = diagnosis; ICD-9 = *International Classification of Diseases*, *Ninth Revision*.

include chronic obstructive pulmonary disease (COPD) (9). COPD is the third most common cause of hospital readmission among Medicare beneficiaries (4). Almost one in four (22.6%) Medicare beneficiaries (4) and 1 in 12 younger adults (40–64 yr old) (10) hospitalized for COPD were readmitted to the hospital within 30 days of discharge.

COPD affects more than 6.2% of adults in the United States, is the third most common cause of death (11), and is the only leading cause of mortality with rising morbidity and mortality (12, 13). The typical disease course of the patient with COPD is punctuated with exacerbations (14–16). Most are treated in outpatient settings; more severe cases, however, require hospitalization. Patients are at increased risk of reexacerbations within the first few weeks of the index exacerbation (17), which can result in hospital readmissions. High rates of readmission among patients with COPD may result from the complexity of the index hospitalization or problems in transition of care or outpatient follow-up after discharge (18).

Claim-based models to predict 30-day readmission exist for CHF, acute myocardial infarction, and pneumonia (19–22). However, similar models are lacking for patients hospitalized for COPD. We hypothesized that an array of patient, provider, and system factors contribute to early readmission among patients hospitalized with COPD. In the current work, we aimed to evaluate the frequency of early hospital readmission rate (within 30 d of discharge) for patients 40 to 64 years old and hospitalized for COPD, and build a risk prediction model based on patient, provider, and system factors that were associated with early readmission.

Methods

Study Population

The study population included commercially ensured patients 40 to 64 years of age and hospitalized with a primary discharge diagnosis of COPD between January 2009 and November 2011 in a large private health insurance plan, which covers approximately 70 million Americans. The Clinformatics Data Mart, managed by OPTUMInsight (Minneapolis, MN), is composed of medical and pharmacy claims data for members in this health plan throughout the United States. The Research Database contains claims data from May 2000 to December 2011 for approximately 51,000,000 current and past members, with a mean continuous enrollment period of approximately 2 years. All files contain

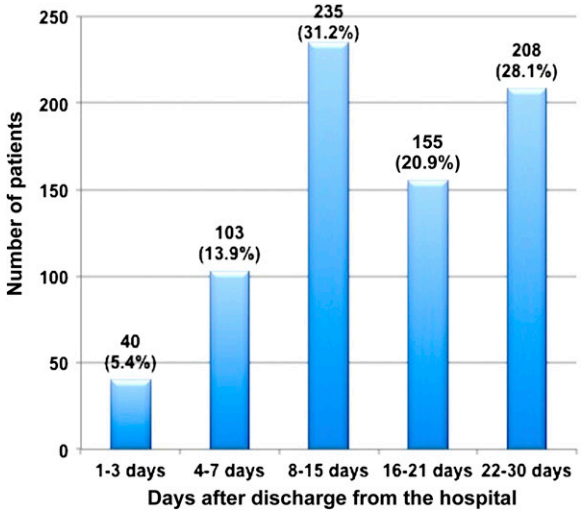

Figure 2. Distribution of early readmission among patients 40–64 years of age and hospitalized with chronic obstructive pulmonary disease between 2009 and 2011.

Table 1. Baseline demographics of patients 40–64 years of age and hospitalized for chronic obstructive pulmonary disease between 2009 and 2011, including those readmitted within 30 days of index hospitalization

	Total (*n* = 8,263)	30-Day Readmission		*P* Value
		No (n = 7,522): *n* (%)	Yes (n = 741): *n* (%)	
Patient Factors				
Age (yr), mean (SD)	56.55 (5.73)	N/A	57.02 (5.53)	0.257
Age group, yr				
40–54	2,729	2,507 (91.9)	222 (8.1)	0.063
55–64	5,534	5,015 (90.6)	519 (9.4)	
Sex				
Female	4,862	4,423 (90.9)	439 (9.1)	0.82
Male	3,401	3,099 (91.1)	302 (8.9)	
Congestive heart failure				
Yes	2,066	1,797 (86.9)	269 (13.1)	<0.001
No	6,197	5,725 (92.4)	472 (7.6)	
Lung cancer				
Yes	347	298 (85.9)	49 (14.1)	0.001
No	7,916	7,224 (91.3)	692 (8.7)	
Anxiety				
Yes	2,206	1,947 (88.3)	259 (11.7)	<0.001
No	6,057	5,575 (92.0)	482 (8.0)	
Alcohol abuse				
Yes	4,372	3,981 (91.1)	391 (8.9)	0.93
No	3,891	3,541 (91.0)	350 (9.0)	
Obesity				
Yes	1,488	1,319 (88.6)	169 (11.4)	0.001
No	6,775	6,203 (91.6)	572 (8.4)	
Depression				
Yes	811	713 (87.9)	98 (12.1)	0.001
No	7,452	6,809 (91.4)	643 (8.6)	
Osteoporosis				
Yes	1,277	1,112 (87.1)	165 (12.9)	<0.001
No	6,986	6,410 (91.7)	576 (8.3)	
Chronic kidney disease				
Yes	468	401 (85.7)	67 (14.3)	<0.001
No	7,795	7,121 (91.3)	674 (8.7)	
Diabetes mellitus				
Yes	2,549	2,272 (89.1)	277 (10.9)	<0.001
No	5,714	5,528 (96.7)	186 (7.3)	
Hypertension				
Yes	5,713	5,158 (90.3)	555 (9.7)	<0.001
No	2,550	2,364 (92.7)	186 (7.3)	
Hyperlipidemia				
Yes	4,242	3,840 (90.5)	402 (9.5)	0.096
No	4,021	3,682 (91.6)	339 (8.4)	
Obstructive sleep apnea				
Yes	1,435	1,276 (88.9)	159 (11.1)	0.002
No	6,828	6,246 (91.5)	582 (8.5)	
Number of comorbidities				
No comorbid conditions	1,261	1,184 (93.9)	77 (6.1)	<0.001
One comorbidities	3,128	2,912 (93.1)	216 (6.9)	
Two comorbidities	2,328	2,110 (90.6)	218 (9.4)	
Three or more comorbidities	1,546	1,316 (85.1)	230 (14.9)	
Provider Factors				
Any COPD medication* 1 yr before hospitalization				
Yes	3,892	3,704 (95.2)	188 (4.8)	<0.001
No	4,371	3,818 (87.3)	553 (12.7)	
ACE inhibitors				
Yes	1,566	1,466 (93.6)	100 (6.4)	<0.001
No	6,697	6,056 (90.4)	641 (9.6)	
Statins				
Yes	1,715	1,614 (94.1)	101 (5.9)	<0.001
No	6,548	5,908 (90.2)	640 (9.8)	

(Continued)

Table 1. (*Continued*)

	Total (*n* = 8,263)	30-Day Readmission		*P* Value
		No (n = 7,522): *n* (%)	Yes (n = 741): *n* (%)	
Long-term oxygen therapy 1 yr before index admittance				
Yes	2,032	1,769 (87.1)	263 (12.9)	<0.001
No	6,231	5,753 (92.3)	478 (7.7)	
System Factors				
Outpatient care in previous 12 mo				
Visit to PCP	3,215	2,921 (90.9)	294 (9.1)	<0.001
Visit to pulmonary specialist	659	576 (87.4)	83 (12.6)	
Visit to both PCP and pulmonary specialist	1,510	1,338 (88.6)	172 (11.4)	
No visit to PCP or specialist	2,879	2,687 (93.3)	192 (6.7)	
Total outpatient visits in previous 12 mo, mean (SD), d	3.23 (4.0)	N/A	4.18 (4.5)	<0.001
PCP visits only, mean (SD)	2.05 (2.9)	N/A	2.56 (3.7)	<0.001
Pulmonary specialist only, mean (SD)	0.83 (2.0)	N/A	1.17 (2.3)	0.008
Number of inpatient hospital visits in 12 mo before index hospitalization, mean (SD)	1.00 (1.1)	N/A	2.01 (2.7)	<0.001

Definition of abbreviations: ACE = angiotensin-converting enzyme; COPD = chronic obstructive pulmonary disease; N/A = not applicable; PCP = primary care physician.
*COPD medication: short/long-acting bronchodilators and/or inhaled or oral corticosteroid.

encrypted patient and provider identifiers, which permit patient-specific longitudinal tracking of patient, hospital, and medication histories. However, race and socioeconomic status are not captured in the database.

Using the *International Classification of Diseases, Ninth Revision* (ICD-9), we included patients hospitalized between January 2009 and November 2011 with primary diagnosis codes for COPD. We excluded patients 65 years of age or older as well as those younger than 40 years, those with incomplete data for the 12 months before the index hospitalization, those transferred to a long-term facility, and those with discharge diagnosis ICD-9 codes of 490 (nonspecific bronchitis) and 493 (asthma). Overall, 8,263 patients 40–64 years of age, with ICD-9 codes of 491.xx, 492.xx, and 496 as their primary diagnoses were included in the study (Figure 1). The university institutional review board approved the study protocol.

Variables

The Research Database contains the following components: the member enrollment file, consisting of demographic information on all health plan enrollees (year of birth, sex, state, and benefits); medical claims records, including diagnosis and procedure codes from all health care sites (inpatient hospital, emergency room, physician's office, or surgery center) for services provided to enrollees; pharmacy claims (drug code, drug names, drug strength, date prescription filled, and days of supply).

Predictor variables. Predictor variables were classified as patient, provider, and system factors. The patient factors included age, sex, and type and number of comorbid conditions before the index admission. We examined comorbidities prevalent in this population based on existing literature and also in our cohort (CHF, lung cancer, alcohol abuse, obesity, depression, osteoporosis, chronic kidney disease (23), diabetes mellitus, hyperlipidemia, and obstructive sleep apnea). We examined the effect of both individual comorbidities, the number of unique comorbidities, and certain combinations.

The provider factors focused on the quality of care within the 12 months before hospitalization and the prescriptions given on discharge. The type of inhaler medications prescribed within a year of the index hospitalization and any prescription of in-home oxygen were recorded for each subject. COPD medications included any prescription of short-acting β agonist, short-acting muscarinic antagonist, long-acting β agonist, long-acting muscarinic antagonist, or inhaled corticosteroid or oral steroid from the 12 months before the index hospitalization to 30 days after discharge. In addition, we recorded any prescription of antibiotics within 30 days of discharge. To examine the protective effect of statins and/or angiotensin-converting enzyme inhibitors (ACE-Is) (24) on COPD readmission we recorded any prescription of statins and ACE-I within the 12 months before the index hospitalization. Claims for oxygen therapy over the 12 months before the index hospitalization and within 30 days of discharge were also recorded.

System factors included number of outpatient visits over 12 months before the index hospitalization, type of COPD care provider seen (primary care physician [PCP], pulmonary specialist, both PCP and specialist), number of inpatient hospitalizations over the 12 months before the index hospitalization, length of stay in the hospital during index hospitalization, discharge follow-up visit, and type of provider seen after discharge. Length of stay during the index hospitalization was categorized as 1–2, 3–4, 5–6, or at least 7 days or more.

Main outcome. The primary outcome was defined as all-cause readmission within 30 days of the discharge day of index hospitalization. The secondary outcome was the reason for and the factors associated with readmission.

Statistical Analysis

In this retrospective cohort study, we used descriptive statistics to report the characteristics of all cohorts and the rates of rehospitalization within 30 days by patient,

provider, and system characteristics. The readmission rates across different levels of each categorical and continuous variable were compared by chi-squared (χ^2) and Student *t* test, respectively.

Two multivariable logistic regression models were built to determine the independent predictors of early readmission. The first model included baseline patient demographic and clinical characteristics, provider factors (prescriptions over the 12 months before index hospitalization), and system factors (type of provider and number of hospitalization within the year before index hospitalization). Then, provider (prescriptions) and system factors (length of stay, discharge follow-up, and type of provider in the discharge follow-up) during hospitalization and within 30 days of discharge were added into the second model. C-statistics with 95% confidence interval (CI) from the receiving operating curves were calculated. We cross-validated the model by splitting the data into derivation and validation cohorts. We used SAS version 9.2 (SAS Institute Inc., Cary, NC) for all statistical analyses. All hypothesis testing was two-sided with significance set at *P* less than or equal to 0.05.

Results

Study Population and Readmission Pattern

Between January 2009 and November 2011, 8,263 patients 40–64 years of age were hospitalized for COPD. All patients were followed up for 30 days after discharge. Of these, 741 (8.9%) were readmitted within the follow-up period. Table 1 presents the baseline characteristics of the entire cohort and those readmitted within 30 days.

Factors Associated with Early Readmission

Univariable analysis. As illustrated in Table 1, patients with a history of CHF, lung cancer, anxiety, obesity, depression, osteoporosis, chronic kidney disease, diabetes mellitus, hypertension, and obstructive sleep apnea were more likely to be readmitted within 30 days, compared with those who did not have these

Table 2. Process of care and predictors of 30-day readmission among patients 40–64 years of age admitted with chronic obstructive pulmonary disease, 2009–2011

	Total COPD Admission	Patients with 30-Day Readmission		*P* Value
		No	Yes	
Provider Factors (within 30 d of Discharge)				
SABA and/or SAMA				
Yes	3,153	2,973 (94.3)	180 (5.7)	<0.001
No	5,110	4,549 (89.0)	561 (11.0)	
Long-acting β agonist				
Yes	172	164 (95.3)	8 (4.7)	<0.001
No	8,091	7,358 (90.9)	733 (9.1)	
Long-acting muscarinic antagonist				
Yes	1,709	1,615 (94.5)	94 (5.5)	<0.001
No	6,554	5,907 (90.1)	647 (9.9)	
Oral glucocorticoids				
Yes	4,894	4,610 (94.2)	284 (5.8)	<0.001
No	3,369	2,912 (86.4)	457 (13.6)	
ICS				
Yes	480	450 (93.7)	30 (6.3)	0.03
No	7,783	7,072 (90.9)	711 (9.1)	
ICS plus LABA				
Yes	2,078	1,965 (94.6)	113 (5.4)	<0.001
No	6,185	5,557 (89.8)	628 (10.2)	
Theophylline				
Yes	308	286 (92.9)	22 (7.1)	0.25
No	7,955	7,236 (91.0)	719 (9.0)	
Any COPD medication during 30 d postdischarge				
Yes	5,807	5,479 (94.3)	328 (5.7)	<0.001
No	2,456	2,043 (83.2)	413 (16.8)	
Any antibiotics during 30 d after index admission				
Yes	4,616	4,328 (93.8)	288 (6.2)	<0.001
No	3,647	3,194 (87.6)	453 (12.4)	
LT/OT (30 d after index admittance)				
Yes	2,266	2,054 (90.6)	212 (9.4)	0.45
No	5,997	5,468 (91.2)	529 (8.8)	
System Factors				
Length of stay during index hospitalization (d), mean (SD)	5.1 (14.9)	N/A	5.7 (14.0)	<0.001
Had a follow-up visit within the 30 d	4,732	4,374 (92.4)	358 (7.6)	<0.001
No follow-up within 30 d of discharge	3,531	3,148 (89.1)	383 (10.9)	

Definition of abbreviations: COPD = chronic obstructive pulmonary disease; ICS = inhaled corticosteroid; LABA = long-acting β agonist; LT/OT = long-term oxygen therapy; N/A = not applicable; SABA = short-acting β agonist; SAMA = short-acting muscarinic antagonist.

comorbidities. There was a stepwise increase in rates of 30-day readmission with increasing number of comorbid medical conditions. For example, patients with none, one, two, and three or more comorbidities had 6.1, 6.9, 9.4, and 14.9% rates of readmissions, respectively ($P < 0.001$). In addition, patients with COPD with certain combination of comorbidities had much higher risk of readmission than others, suggesting a differential role for coexisting comorbidities. For example, patients with COPD with CHF and osteoporosis (n = 74) had the highest risk for readmission (21.0%), followed by those with CHF and anxiety (n = 100; 18.2%), CHF and depression (n = 83; 15.9%), and CHF and alcohol abuse (n = 129; 14.4%).

Patients who were not receiving any COPD medications, statins, or ACE-Is in the year before hospitalization had higher rates of 30-day readmissions. As expected, patients with severe disease (as suggested by long-term oxygen therapy use or being seen by a pulmonary specialist) had higher rates of 30-day readmissions (Table 1). We tested for differential effects of statins on 30-day readmission in patients with and without hyperlipidemia. Patients receiving statins for hyperlipidemia had lower odds of 30-day readmission (odds ratio [OR], 0.6; 95% CI, 0.4–0.8) compared with those patients without hyperlipidemia (OR, 1.1; 95% CI, 0.6–2.0). However, the effect of ACE inhibitors on 30-day readmission was not different in patients with or without history of CHF ($P = 0.06$).

Table 2 shows the process of care measures during index hospitalization. As shown, patients who did not receive a prescription for a short-acting β agonist/short-acting muscarinic antagonist, long-acting β agonist, long-acting muscarinic antagonist, or inhaled glucocorticoids within 30 days of discharge had higher rates of readmission. Patients who received any prescription for COPD medications and/or antibiotics had lower rates of 30-day readmission. For example, rates of 30-day readmission were 16.8% for patients who received no prescriptions for COPD medications within 30 days of discharge, compared with 5.9% in those who received prescriptions for any COPD medications ($P < 0.001$). Patients who had a follow-up visit within 30 days of discharge had a readmission rate of 7.6%, compared with 10.9% in those who did not have follow-up visit postdischarge ($P < 0.001$). There was no statistically significant difference in rate of readmission in terms of time to follow-up visit since discharge or type of provider seen after discharge.

Table 3 presents the primary reason for each readmission. The most common reason for readmission, within the first 30 days after discharge, was COPD (27.4%), followed by respiratory failure (14.3%) and symptoms involving the respiratory system (8.5%). Other reasons for readmission were related to cardiovascular comorbidities. Half of the patients were readmitted within the first 15 days and 19% within the first 7 days (Figure 2).

Multivariable analysis. Table 4 presents the multivariable analysis of factors associated with 30-day readmission. As shown, female patients had lower odds of readmission (OR, 0.9; 95% CI, 0.7–0.9). The highest odds of readmission were associated with patients with lung cancer comorbidities (OR, 1.6; 95% CI, 1.3–2.1). Patients who had a prescription for statins in the 12 months before hospitalization had lower odds of readmission (OR, 0.6; 95% CI, 0.5–0.7). Prescriptions for antibiotics within 30 days of discharge were associated with a lower likelihood of a 30-day readmission (OR, 0.8; 95% CI, 0.6–0.9).

Patients with shorter (≤2 d) and longer (≥7 d) stays had increased odds of a 30-day readmission. Patients who had a follow-up within 30 days of discharge had lower odds of readmission (OR, 0.7; 95% CI, 0.6–0.9) compared with those who did not have a follow-up visit to an outpatient provider postdischarge.

Finally, we examined the C-statistics of the model in predicting 30-day readmission. A model including only the patient characteristics had a C-statistic of 0.677 (95% CI, 0.656–0.697). The addition of provider- and system-level factors postdischarge significantly enhanced the model prediction to 0.717 (95% CI, 0.702–0.732). We cross-validated the final model by randomly splitting the cohort into a deviation set and a validation set. The C-statistic of the validation sample was 0.73, with a 95% CI of 0.70–0.76. In addition, the assessment of the predictive accuracy of our final model indicated that the rate of readmissions was 4.3% for patients with the predicted probability of readmission in the bottom quartile compared with 20.3% for the patients with the predicted probability of readmission in the top quartile. There was a 4.7-fold increase in readmission rates between these two groups of patients.

Table 3. Reasons for 30-day readmission among patients discharged with primary discharge diagnosis of chronic obstructive pulmonary disease

Reason for Readmission*	n (%)
COPD (491, 492, 496)	203 (27.4)
Respiratory failure (518)	106 (14.3)
Symptoms involving respiratory system (786)	63 (8.5)
Pneumonia (486)	31 (4.2)
Heart failure (428)	17 (2.3)
Cardiac dysrhythmia (427)	16 (2.2)
Coronary atherosclerosis (414)	15 (2.0)
Lung cancer (162)	13 (1.8)
Septicemia (038)	12 (1.6)
Acute pulmonary heart disease (415)	7 (0.9)
Other	258 (34.8)
Total	741

Definition of abbreviation: COPD = chronic obstructive pulmonary disease.
*Numbers in parentheses represent the *International Classification of Diseases, Ninth Revision* (ICD-9) codes.

Discussion

One in 11 patients 40–64 years of age and hospitalized with COPD was readmitted within 30 days of the index hospitalization. Patient (sex, comorbid conditions), provider (specific medications prescribed), and system (process of care) factors predicted early readmission. To our knowledge, this is the first study to examine potentially modifiable provider- and system-level factors associated with readmission.

The early readmission rate of 8.9% in our cohort is similar to another study on a similar patient population (10). Prior reports have shown the 30-day readmission rate for patients with COPD to be 14.3–24% (4, 25). Among Medicare beneficiaries, the national readmission rates are much higher (4, 5). Low early readmission rates in our study can be explained by the relatively younger age group and fewer comorbidities.

In concordance with previous studies the number of comorbidities directly correlates with the frequency of 30-day

readmission after hospital discharge (26). Those with conditions such as CHF, lung cancer, anxiety, depression, and osteoporosis had a higher likelihood of readmission. Among patients with chronic debilitating medical conditions, anxiety and depression are common ailments (27). The prevalence of anxiety and depression is high in the COPD population (28–30), with the risk of depression in those with severe disease nearly 2.5 times higher than normal (30). Whether the worsening of COPD induces anxiety and depression or a history of anxiety and depression causes lack of adherence to COPD management is unknown. The presence of these psychosocial factors has been associated with increased readmission in patients with COPD (31–33). Patients with anxiety and depression have poor compliance with medications (34, 35). This association further underscores the need to tailor efforts toward proper identification and treatment of anxiety and depression. However, the benefit of treating these psychological conditions in reducing readmission is unknown.

The physician plays a vital role in preventing hospital readmission for COPD. Patients who were prescribed statins in the 12 months before admission had lower rates of 30-day readmission. Current interest has focused on the benefit of statins in reducing inflammatory markers that contribute to COPD inflammation (36), specifically regarding mortality. In the Rotterdam Study of statin use in 363 patients with COPD, long-term (>2 yr) statin use was associated with a nearly 40% decreased risk of death compared with no prior use (37). In a cohort study it was shown that statin use in patients with COPD led to a 30% reduction in all-cause mortality at 3–4 years after first hospital admission with adjustment for prior history of diabetes and cardiovascular disease (38). The benefit of statins in reducing all-cause mortality and respiratory-related mortality has been shown in several studies (38, 39). The National Heart, Lung, and Blood Institute sponsored randomized clinical trial entitled Simvastatin Therapy for Moderate and Severe COPD (STATCOPE) is currently investigating the effects of statin therapy in patients with COPD. Further studies will be needed to confirm the benefit of statin therapy in reducing readmissions.

Table 4. Multivariable analysis of factors associated with 30-day readmission of patients aged 40–64 years and admitted for chronic obstructive pulmonary disease between 2009 and 2011

Variable	Odds Ratio (95% CI)	*P* Value
Patient Factors		
Age		
40–54 yr	1.0	0.386
55–64 yr	1.1 (0.9, 12.9)	
Sex		
Male	1.0	0.025
Female	0.9 (0.7, 0.9)	
Congestive heart failure		
No	1.0	0.021
Yes	1.2 (1.0, 1.5)	
Lung cancer		
No	1.0	0.035
Yes	1.6 (1.3, 2.1)	
Alcohol abuse		
No	1.0	0.457
Yes	1.1 (0.9, 1.3)	
Obesity		
No	1.0	0.407
Yes	1.1 (0.9 1.4)	
Anxiety		
No	1.0	0.003
Yes	1.5 (1.2, 1.8)	
Depression		
No	1.0	0.016
Yes	1.3 (1.1, 1.8)	
Osteoporosis		
No	1.0	0.008
Yes	1.3 (1.1, 1.6)	
Hypertension		
No	1.0	0.507
Yes	1.1 (0.9, 1.3)	
Chronic kidney disease		
No	1.0	0.395
Yes	1.1 (0.8, 1.5)	
Hyperlipidemia		
No	1.0	0.064
Yes	1.2 (0.9, 1.4)	
Diabetes mellitus		
No	1.0	0.816
Yes	1.0 (0.9, 1.2)	
Obstructive sleep apnea		
No	1.0	0.811
Yes	0.9 (0.8, 1.2)	
Provider Factors		
Prescription of ACE inhibitors 12 mo before index admission		
No	1.0	0.029
Yes	0.8 (0.6, 0.9)	
Prescription for statins 12 mo before index admission		
No	1.0	<0.001
Yes	0.6 (0.5, 0.7)	
Being on long-term oxygen treatment 12 mo before hospitalization		
No	1.0	0.344
Yes	1.1 (0.9, 1.3)	
Prescription of SABA/SAMA within 30 d of discharge		
No	1.0	0.021
Yes	0.8 (0.6, 0.9)	
Prescription of LABA within 30 d of discharge		
No	1.0	0.132
Yes	0.6 (0.3, 1.2)	

(Continued)

Table 4. (*Continued*)

Variable	Odds Ratio (95% CI)	*P* Value
Prescription of LAMA within 30 d of discharge		
No	1.0	0.159
Yes	0.8 (0.7, 1.1)	
Prescription of oral steroid within 30 d of discharge		
No	1.0	<0.001
Yes	0.7 (0.5, 0.8)	
Prescription of ICS within 30 d of discharge		
No	1.0	0.456
Yes	1.0 (0.7, 1.5)	
Prescription of LABA/ICS within 30 d of discharge		
No	1.0	0.194
Yes	0.9 (0.7, 1.1)	
Prescription of any antibiotic within 30 d of discharge		
No	1.0	0.001
Yes	0.8 (0.6, 0.9)	
System Factors		
Length of stay		
1–2 vs. 3–4 d	1.3 (1.0, 1.5)	0.019
5–6 vs. 3–4 d	1.1 (0.8, 1.4)	0.626
>7 vs. 3–4 d	1.2 (1.1, 1.5)	0.010
Hospitalization		
None vs. ⩾3 admissions	0.4 (0.3, 0.6)	<0.001
One vs. ⩾3 admissions	0.6 (0.4, 0.7)	<0.001
Two vs. ⩾3 admissions	0.7 (0.6, 0.9)	0.021
Follow-up visit within 30 d		
No	1.0	<0.001
Yes	0.7 (0.6, 0.9)	

Definition of abbreviations: ACE = angiotensin-converting enzyme; CI = confidence interval; ICS = inhaled corticosteroid; LABA = long-acting β agonist; LAMA = long-acting muscarinic antagonist; SABA = short-acting β agonist; SAMA = short-acting muscarinic antagonist.

Patients who were prescribed steroids and antibiotics on discharge were less likely to be readmitted within 30 days. The positive effects of steroids in the management of COPD have been well demonstrated in randomized clinical trials (40) and administrative data (41). Patients who are prescribed oral steroids on admission will have faster improvement in FEV_1, shorter hospital stays, and improvements in patient-assessed dyspnea and quality of life (40, 41). In a retrospective cohort study of patients 40 years of age or older, Rothberg and colleagues found that, in patients with COPD, early antibiotic administration was associated with lower rates of readmission and lower rates of inpatient mortality (42). In a study of more than 53,000 patients, Stefan and colleagues found that, in patients admitted with COPD and who were treated with steroids, the addition of antibiotics was associated with a 40% reduction in risk of in-hospital mortality and a 13% improvement in rate of readmission (43). Despite promising results from both randomized clinical trials and numerous administrative data on the impact of steroids and antibiotics on COPD exacerbation, not all exacerbations are bacterial and routine use of antibiotics remains controversial.

Although modifiable patient and physician factors may reduce the likelihood of readmission, system factors that can be modified should not be overlooked. In our study, we found that those patients with a follow-up visit with either a PCP or pulmonologist had lower rates of readmission. A study of the Medicare population found similar results (44). Efforts to improve follow-up visits through automated scheduling on admission or reminder phone calls should be targeted. The efficacy of this intervention was shown in conditions such as CHF (45). Our results of higher readmission rates for patients with low (⩽2 d) or higher (⩾7 d) lengths of stay are consistent with a prior study (46). The observed difference in readmission rates depending on the type of provider seen in the 12 months before index hospitalization could be attributable to selection bias, as sicker patients are more likely to be seen by a pulmonary physician. Patients with too short or too long a hospital stay have higher rates of readmission, consistent with prior studies (46, 47). Our results may indicate that patients discharged after 2 days or less are undertreated, causing earlier readmission. Patients who are admitted for 5 days or more may have more severe hospitalizations, refractory disease, or suffer from nosocomial infections causing earlier readmission.

The 30-day readmission risk prediction models for CHF, acute myocardial infarction, and pneumonia are based on administrative claims and have moderately discriminatory C-statistics and are mostly driven by patient factors (21, 22). Provider and system factors are potentially modifiable and, in our study, adding these factors to patient factors significantly improved the C-statistics of the model to predict 30-day readmission. Future studies should include provider and system factors in risk prediction models.

Our study has several limitations. We used ICD-9 to identify patients hospitalized with COPD. Previous studies suggested that this approach had low sensitivity (48). We repeated the analysis by addition of ICD-9 codes 490 and 493 to the baseline cohort. The 30-day readmission rates were 7.73 and 7.68%, respectively. Using administrative claim data, we do not have information on the severity of patients' COPD or the complexity of the index hospitalization. These factors can confound the rate of readmission, as sicker patients are more likely to be readmitted. Similarly, because our study cohort was limited to ages 40–64 years these results cannot be generalized to fee-for-service Medicare beneficiaries. Socioeconomic status is an important determinant of readmission and was not captured in the database. Although the prescription of certain medications is associated with lower readmission rate, the analysis does not take into account adherence to medications. This limitation may underinflate the benefit of steroids, antibiotics, and long-acting β agonists/long-acting muscarinic antagonists as

patients who were prescribed these medications, but were nonadherent, and then were readmitted within 30 days should be excluded. Finally, using patient, provider, and system factors, we were able to build a risk prediction model that was cross-validated in the current data set but needs validation in an independent sample.

In summary, patient, provider, and system factors predict COPD readmission. Modifiable provider and system factors should be targeted to decrease the rate of readmission within 30 days. ■

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