# The impact of Hospital Readmission Reduction Program on chronic obstructive pulmonary disease risk factors: a systematic review

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**Background:** The objective of this systematic review is to summarize and assess the risk factors associated with chronic obstructive pulmonary disease (COPD) readmission following the enactment of the Patient Protection and Affordable Care Act and the Center for Medicare and Medicaid Services' Hospital Readmission Reduction Program in 2015. Before the enactment of the Act, addressing the rising rate of COPD-related readmission was a quality improvement effort. However, the Act allowed for the creation of financial penalties to incentivize these improvements and set the reduction of readmission as a priority.

**Methods:** This study systematically examined electronic databases from 2010–2020. Data were extracted and divided into two time periods: after the introduction of the Patient Protection and Affordable Care Act (2010–2014) and after the addition of COPD as a Hospital Readmission Reduction Program measure (2015–2020). Studies were screened based on inclusion and exclusion criteria. The study was grounded in the Ecological Model to assess COPD readmission risk factors.

**Results:** A total of 30 studies were included in the analysis. At the individual level, comorbidities were the most widely explored risk factors for readmission risk amongst all articles, though 2015–2020 articles introduced behavioral health comorbidities as newly explored risk factors. At the community level, though largely unexplored in 2010–2014 articles, discharge location as a readmission risk factor was examined in several 2015–2020 articles.

**Conclusions:** Overall, no major differences in the types of COPD readmission risk factors examined were found, though new, previously unexplored risk factors were observed. Future research should aim to utilize Centers for Medicare and Medicaid Services Hospital Readmission Reduction Payment readmission data or methodology to gain a comprehensive understanding of the impact of the Hospital Readmission Reduction Program and risk factors for readmission under the program.

**Keywords:** Chronic obstructive pulmonary disease (COPD); readmission risk factors; hospital readmission; Hospital Readmission Reduction Program

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## Introduction

The passage of the Patient Protection and Affordable Care Act (ACA) in 2010 formally introduced a shift from fee-for-service reimbursement to a value-based, pay-for-performance reimbursement approach. This new payment scheme has radically changed the healthcare environment. The ACA introduced a multipronged approach to improving health care. It targeted access to healthcare, affordability of healthcare, and the quality and efficiency with which care is delivered in hopes of reducing wasteful spending (1). Section 3025 of the ACA established the Centers for Medicare and Medicaid Services' (CMS) Hospital Readmissions Reduction Program (HRRP), aimed at reducing avoidable 30-day hospital readmissions and structured so that hospitals are reimbursed for services rendered based on their performance (2). This is done through a calculated payment adjustment factor, in which hospitals in the lowest-performing quartile for readmissions receive a maximum of a three percent payment reduction (2). The risk of payment reduction for poor performance and increased transparency on hospital performance via publicly available readmission rates (unplanned hospital visits) on the CMS Hospital Compare website, hold hospitals more accountable for the care they provide. Hospitals are thereby incentivized to provide quality care to avoid penalties and maintain or improve their reputations.

Since its implementation, the HRRP has experienced a variety of modifications to the readmission measures (*Table 1*)—currently, there are six measures utilized: (I) acute myocardial infarction (AMI); (II) heart failure (HF); (III) pneumonia (PN); (IV) chronic obstructive pulmonary disease (COPD); (V) total hip arthroplasty (THA) and or total knee arthroplasty (TKA); and (VI) coronary artery bypass graft (CABG) surgery (2).

In 2015, COPD was included as a readmission penalty measure (3). Approximately 16 million Americans are diagnosed with COPD and in 2018, COPD had the fourth highest mortality rate in the U.S. (4,5). Furthermore, in 2010, total costs for COPD were $32.1 billion, with Medicare carrying a significantly higher burden of the cost—COPD costs for 2020 are expected to reach $49 billion (6). In addition to its introduction as a readmission measure in the HRRP, efforts to mitigate the negative impacts of COPD include its inclusion as a Healthy People 2020 area of focus (due to its preventative and treatable nature) and the National Institutes of Health and Centers for Disease Control and Prevention's joint development of the COPD National Action Plan (7,8).

Previous literature reviews have attempted to identify risk factors of patients with COPD on either all-cause readmissions or COPD-related readmissions through the examination of both United States (U.S.) and international studies. However, HRRP is a uniquely U.S. policy-oriented approach toward COPD readmissions, thus there is a need to examine U.S.-based studies looking at COPD risk factors, but to date, no reviews have examined whether there were any significant changes in identified risk factors or interventions amongst studies that were completed pre-COPD inclusion into the HRRP and post-COPD inclusion into the HRRP in the U.S. The HRRP program has caused healthcare organizations and health services researchers to redouble their efforts to reduce COPD readmission due to associated financial penalties, in part by identifying the core risk factors for readmission that are within the walls of the facility (9,10). The goal of this study is to extend the literature by examining and identifying

**Table 1** HRRP measures utilized per fiscal year range

| HRRP targeted conditions | 2013–2014 | 2015–2016 | 2017–2018 | 2019–2020 |
|---|---|---|---|---|
| AMI | * | * | * | * |
| HF | * | * | * | * |
| PN | * | * | * | * |
| COPD | | * | * | * |
| THA and or TKA | | * | * | * |
| CABG surgery | | | * | * |

*, cells are indicative of condition being utilized by the HRRP. HRRP, Hospital Readmissions Reduction Program (2); AMI, acute myocardial infarction; HF, heart failure; PN, pneumonia; COPD, chronic obstructive pulmonary disease; THA, total hip arthroplasty; TKA, total knee arthroplasty; CABG, coronary artery bypass graft.

key risk factors for COPD and how they differ pre- and post-HRRP implementation. Findings from the review can inform policymakers and health services researchers of how the inclusion of a COPD measure that is tied to a financial incentive may have affected the types of risk factors considered in the extant research. We present the following article in accordance with the PRISMA reporting checklist (available at https://jhmhp.amegroups.com/article/view/10.21037/jhmhp-22-41/rc).

## Background

### COPD

COPD is a serious chronic condition that worsens over time due to progressive lung damage, causing an individual's airway to become more and more obstructed. Individuals with COPD typically have chronic bronchitis or emphysema (11). Several factors such as respiratory infections, genetics, and pollutants could impact individuals' lung function and potentially lead to COPD (12). Smoking is the biggest contributing factor to developing COPD, and as such, smoking cessation interventions presumably have the most impact on preventing or decreasing the incidence of COPD (13). Research suggests that COPD is more prevalent in rural areas in the U.S. (14,15). The geographic prevalence and mortality of COPD vary across states and regions. Based on 2014 data, states with high prevalence and high mortality rates of COPD were Alabama, Arkansas, Tennessee, Kentucky, West Virginia, and Indiana (16). Surveillance data has also indicated that COPD is more highly prevalent in American Indians/Alaska Natives and multiracial individuals (8).

### Acute exacerbation & COPD readmission

Acute exacerbations of COPD occur when COPD symptoms (such as coughing or difficulty breathing) flare up for days or weeks and can be due to upper respiratory infections, amongst other things (11). Several treatment options are available for acute exacerbations of COPD such as antibiotics, types of steroids, and in extreme cases, ventilation. COPD hospitalizations make up over 70% of all medical expenditures related to COPD (17).

Several interventions targeted at changing patient lifestyle and/or treatment could be used as effective prevention tools for an acute exacerbation of COPD and potential readmission. The biggest lifestyle change, and arguably the most effective

intervention, includes smoking cessation. Continued smoking cessation assists in decreasing the rate at which lung function declines in COPD and therefore can lead to decreases in hospitalizations due to acute exacerbations of COPD (18). Furthermore, the administration of inactive flu vaccines (*vs.* patients with placebo vaccines) can decrease the risk of respiratory failure (19) and seasonal flu vaccines have been associated with lower exacerbations and hospitalizations (20). While the education of patients with COPD and case management as singular interventions are not sufficient in reducing acute exacerbations in COPD, a combination of case management, education, and regular access to a provider is recommended as a viable prevention method (21).

Several systematic reviews have examined the risk factors for COPD readmission. One review found that factors such as comorbidities, previous hospitalization, and a higher length of stay (LOS) were risk factors for 30- and 90-day readmissions (22). A 2020 systematic review of international studies assessed risk factors associated with COPD readmissions. Findings showed previous hospitalizations were a significant risk factor for COPD readmissions, but because risk factors of COPD readmissions varied across the board, no one factor related to readmissions could be generalizable (23). Previous systematic reviews have also examined international interventions associated with decreased readmissions after COPD exacerbations but found no clear interventions that were associated with decreased readmissions (24).

In the U.S., with the introduction of the ACA, readmissions for conditions such as COPD are now non-reimbursable and can result in financial penalties for hospitals. Hospitals are incentivized to focus on improving the quality of care they provide, and as such, understanding the hospital readmission risk factors among patients with COPD/acute exacerbation of COPD is an important goal. In such cases, the ACA's introduction of the HRRP may have catalyzed hospitals' moves to examine factors outside of their scope of care, but that may nonetheless impact patient health, such as community factors and social determinants of health.

## Evaluation framework

The Ecological Model on Health Promotion examines behavior as a function of factors at five intersecting levels: individual, interpersonal, organizational, community, and public policy (25). The individual-level includes factors that are personal to oneself, such as age and knowledge.

**Table 2** Search terms utilized

| General terms | Variation/combination |
| --- | --- |
| Chronic obstructive pulmonary disease | "COPD" |
| | "COPD Exacerbation" |
| | "Acute Exacerbation of COPD" |
| | "AECOPD" |
| | "Chronic Asthmatic Bronchitis" |
| | "Chronic Bronchitis" |
| | "Emphysema" |
| Readmission | "Rehospitalization" |
| | "Hospital readmission" |
| | "Patient readmissions" |
| | "30-day readmission" |
| | "60-day readmission" |
| | "90-day readmission" |
| | "Risk-adjusted readmission" |
| | "Early readmission" |
| Hospital Readmissions Reduction Program | "HRRP" |
| | "HRRP database" |
| | "CMS HRRP" |
| | "CMS" |
| Risk factors | "Smoking" |
| | "Psychological" |
| | "Physical activity" |
| | "Early Therapy" |
| | "Pulmonary Rehabilitation" |
| | "Prediction" |

COPD, chronic obstructive pulmonary disease; AECOPD, Acute Exacerbation of COPD; HRRP, Hospital Readmissions Reduction Program; CMS, Centers for Medicare and Medicaid Services.

The interpersonal level is indicative of an interaction of the individual with society/organizations. This analysis primarily focuses on how the individual interacts with the health care system, including both hospitals or other care points of access and their physicians. The organizational level considers group culture within an entity. The community level involves behaviors and interactions of individuals and organizations within a specified area, and the public policy level encompasses local, state, and national policies.

Risk factors will initially be examined to determine whether their impact was at the patient or hospital level. Patient risk factors are patient-driven characteristics like patient demographics, and hospital risk factors are organization-driven characteristics like organizational structure. Doing so will assist in assessing if the risk factor could be addressed by administrative hospital policies/procedures or by medical care/patient outreach initiatives. We will expand these factors further by applying the Ecological Model to assess these categories. The Ecological Model will be used to group readmission risk factors based on four levels: individual, interpersonal, organizational, and community. These levels are discussed in the context of the public policy level, specifically HRRP. Expanding our assessment further by aligning each risk factor's position amongst the ecological model levels allows for a more in-depth understanding of its impact. This is because while a risk factor may have an impact at the patient level (e.g., patient socioeconomic status, age, and medication), that risk factor may fall under different levels of the ecological model: individual (age), interpersonal (medication), and community (socioeconomic status), thus allowing a better view of the influence of an external environment of patient-level/community factors.

## Methods

### Database searches

The databases utilized in this literature review were Google Scholar, Dove Medical Press, PubMed, and ScienceDirect. Searches of these databases were conducted in November and December of 2020, with search terms initially focused on the general terms: "chronic obstructive pulmonary disease", "readmission(s)", and "Hospital Readmission Reduction Program" as well as variations of these terms (e.g., "COPD"). Subsequent searches using specific risk factors as search terms were used to further narrow the literature. Some of these terms were included based on their well-known relationship to COPD, such as "smoking". Others, such as "psychological", were included via a snowballing methodology in which studies discovered during searches using other search terms identified that topic as a risk factor. *Table 2* provides a complete list of the search terms.

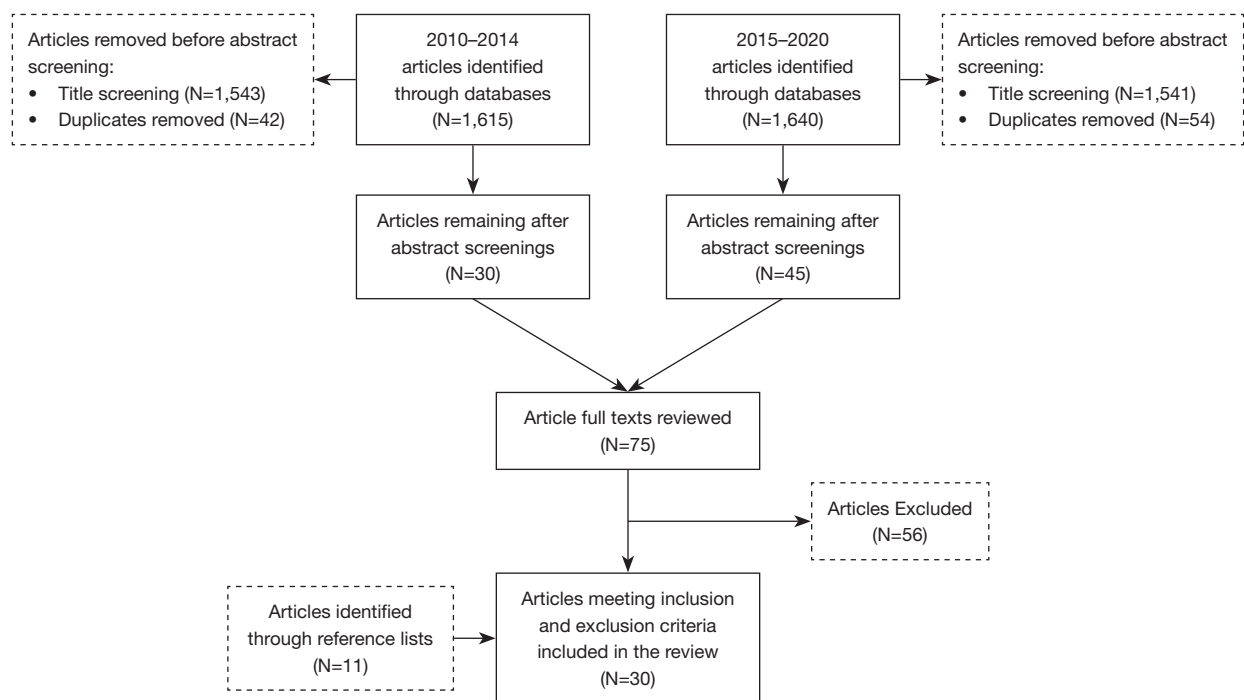Two searches of article publication time frames (prior

**Figure 1** Methodology of systematic review of COPD readmission risk factors. COPD, chronic obstructive pulmonary disease.

to HRRP implementation 2010–2014 and post HRRP implementation 2015–2020) were conducted independently in each database to align with the study purpose of comparing risk factors prior to and after HRRP inclusion of COPD as a readmission measure. Only U.S. studies were included as the HRRP is unique to the U.S. These searches produced 1,615 articles for 2010–2014 and 1,640 articles for 2015–2020 (*Figure 1*). EndNote was used to organize the studies and remove duplicates. For the 2010–2014 searches, 30 articles remained after title and abstract screenings and the removal of 42 duplicates. Similarly, for the 2015–2020 searches, 45 articles remained after title and abstract screenings and the removal of 54 duplicates. These articles were removed upon initial review as they were determined to not primarily examine COPD readmission risk factors among U.S. hospitals. In total, 75 articles were considered for full-text review and were subject to inclusion and exclusion criteria.

The following criteria were applied to studies regardless of the year published: (I) study designs that were cohort, retrospective, cross-sectional, and longitudinal were included; (II) focused on patients with COPD and COPD exacerbation; (III) focused on all-cause COPD readmissions (risk-adjusted and non-risk adjusted). The studies published

between 2015–2020 were limited to: (I) those that were presumed to use risk-adjusted CMS HRRP data or methodology (e.g., did not specify that the readmission was calculated similarly or differently than HRRP), and (II) those that explicitly said they used HRRP data or used HRRP methodology.

Upon screening full texts for inclusion and exclusion criteria, 6 articles were included for 2010–2014 and 13 were included for 2015–2020. In December 2020, a further 11 articles identified through reference lists and previous systematic reviews met inclusion and exclusion criteria, resulting in 30 articles to be utilized in this systematic review. A summary of each of the articles can be found in the Supplementary file (Tables S1,S2). One author conducted the search, engaged in title and abstract screenings, applied inclusion/exclusion criteria to full-text articles, and collected information from each article. The articles included underwent no formal quality assessment or evaluation of findings, and the study investigators of these articles were not contacted to obtain or confirm any missing information.

The main information sought was stated risk factors for COPD readmission and whether they are increasing or decreasing factors respective to the likelihood of COPD

readmission. These factors were then organized and presented in accordance with the Social Ecologic Model.

## Results

### Assessment of modifiability of risk factors

Methodologic information on each article was documented, such as the type of database utilized to assess readmission risks (administrative such as claims data or medical record/chart review), participant inclusion/exclusion criteria (e.g., only VA hospitals were included or only patients that were White, African American, or Hispanic were included), and the geographic area included in the analysis (national or state-specific)—more detailed information on the inclusion/exclusion criteria utilized by the authors of these included studies and geographic area information can be found in *Table 3*.

Databases and geography were examined to assess the generalizability of the risk factors identified. Based on the type of risk factor, the modifiability of the risk factor was evaluated—that is, to what degree patients or hospitals would be able to modify the risk factors to decrease readmission rates among patients with COPD. Modifiability scores were assessed through a three-point Likert scale: a score of 1 was indicative of a risk factor that would be very difficult to modify (such as hospital location), a score of 2 represented a somewhat modifiable risk factor (such as LOS or insurance), and a score of 3 indicated a very modifiable risk factor (such as activity level). Results of the modifiability analysis are presented in *Table 4* (2010–2014) and *Table 5* (2015–2020).

Among 2010–2014 articles, at the individual and interpersonal level risk factors varied at the low [1] and high [3] end of the modifiability spectrum. At the individual level, most risk factors had a modifiability level of 1 (comorbidities, COPD severity, and gender), whereas activity level had a modifiability level of 3. At the interpersonal level, half of the factors (exacerbation and number of hospitalizations) had a modifiability level of 1, and the other half (respiratory medication and prescriptions or breathing treatments) had a modifiability level of 3. At the organizational level, factors such as hospital teaching status and volume of COPD patients had a modifiability level of 3, whereas the LOS had a modifiability level of 2. At the community level, most risk factors were difficult (patient socioeconomic status) and somewhat difficult (insurance type) to modify.

Among 2015–2020 articles, more so than any other level, most individual-level risk factors were very difficult to modify (level 1), including comorbidities, age, COPD severity, gender, and race/ethnicity. Only one risk factor, activity level, was a very modifiable (level 3) risk factor. At the interpersonal level, factors were at the opposite spectrum of modifiability, with respiratory medication being very modifiable and the use of healthcare services before the index period being very difficult to modify. Most risk factors at the organizational level were somewhat modifiable (level 2), including LOS, hospital characteristics such as tobacco services, and competition. Hospital staff responsiveness was a very modifiable factor, while other hospital characteristics such as teaching status and the number of beds were categorized as very difficult to modify. With respect to hospital staff responsiveness, authors utilized the Hospital Consumer Assessment of Healthcare Providers and Systems (HCAHPS) measure of responsiveness based on two questions related to the frequency with which hospital staff assisted patients as soon as the assistance was requested (26). Lastly, community-level factors differ across the modifiability spectrum. Risk factors that were somewhat difficult to modify included discharge location and insurance type. Risk factors such as partial/full smoke-free policy were very modifiable, but other factors such as patient socioeconomic status and county characteristics were very difficult to modify.

### Individual-level risk factors

Across both 2010–2014 and 2015–2020 articles, comorbidities were among the most widely examined risk factors but also produced somewhat mixed results. Six articles published between 2010 and 2014 identified specific comorbidities as contributing to an increased risk among COPD patients for readmission (27-33). Among the studies published between 2015–2020, the most widely examined risk factors included a variety of comorbidity measures such as comorbidities themselves, the number of comorbidities, comorbidity burden, and the Charlson Comorbidity Index (CCI). Specifically, nine of these articles identified comorbidities as a risk factor for increasing readmission among COPD patients (34-42), one found that the number of comorbidities was a risk factor for decreasing the risk of readmission (43), and another found mixed results relative to comorbidities—that is that some comorbidities such as heart disease decreased readmission risks while others like lung cancer increased readmission risks (44). Within

**Table 3** Characteristics of literature examined

| Year | First author | Data type | Unique inclusion/exclusion criteria | Geography |
|---|---|---|---|---|
| 2012 | Nantsupawat | Medical records | | State: TX |
| 2013 | Baker | Administrative | | National |
| 2013 | Bollu | Administrative | | National |
| 2013 | Moran | Medical records | | State: TX |
| 2014 | Chawla | Medical records | | State: CT |
| 2014 | Nguyen | Medical records | EC: patients in observational stay unit | State: CA |
| 2014 | Sharif | Administrative | IC: data comes only from members of private national health plan (no race or socioeconomic status documented) | National |
| 2014 | Sjoding | Administrative | | National |
| 2015 | Candrilli | Administrative | | National |
| 2015 | Coughlin | Medical records | EC: patient home had no electricity or had insect infestation | State: GA |
| 2015 | Nguyen | Medical records | | State: CA |
| 2015 | Roberts | Medical records | | City, State: Albuquerque, NM |
| 2015 | Shah | Administrative | | States: CA, FL, IL, NY, OH, PA, TX |
| 2015 | Yu | Administrative | | National |
| 2016 | Bashir | Medical records | | State: PA |
| 2016 | Qing | Administrative | | National |
| 2016 | Simmering | Administrative | IC: patients who left against medical advice | State: CA |
| 2016 | Singh | Administrative | | National |
| 2017 | Lau | Administrative | | States: NY, CA, FL, WA |
| 2017 | Rinne | Administrative | IC: VA hospitals only | National |
| 2018 | Jacobs | Administrative | | National |
| 2018 | Rezaee | Medical records | | State: MI |
| 2018 | Spece | Medical records | IC: discharges within VA Integrated Service Network (VISN-20): 6 hospitals in specific region | Region: Pacific Northwest |
| 2018 | Yang | Administrative | | National |
| 2019 | Keshishian | Administrative | | National |
| 2019 | Nastars | Administrative | EC: races not White, African American or Hispanic; Medicare HMO enrollees within 1 year of index or 30 days post discharge | National |
| 2019 | Stallings-Smith | Administrative | | National |
| 2020 | Goto | Administrative | | National |
| 2020 | Lin | Administrative | | State: AR, FL, IA, MA, NJ, NE, NY, UT, WA |
| 2020 | Roberts | Administrative | EC: patient discharged anywhere other than home | National |

EC, exclusion criteria; IC, inclusion criteria; VA hospital, Veteran Affairs hospital; HMO, Health Maintenance Organization; TX, Texas; CA, California; CT, Connecticut; GA, Georgia; NM, New Mexico; FL, Florida; IL, Illinois; NY, New York; OH, Ohio; PA, Pennsylvania; WA, Washington; AR, Arkansas; IA, Iowa; MA, Massachusetts; NJ, New Jersey; NE, Nebraska; UT, Utah; MI, Michigan.

**Table 4** Ecological model level assessment of risk factors identified for readmission after ACA enactment (2010–2014)

| Risk factor | Number of studies | Articles | Factor level | Impact on readmission | Data type | Geography | Modifiability |
|---|---|---|---|---|---|---|---|
| Individual level | | | | | | | |
| Comorbidities (example: diabetes, anemia) | 6 | Baker, 2012; Chawla, 2014; Moran, 2013; Nantsupawat, 2012; Nguyen, 2014; Sharif, 2014 | Patient | Increases | Administrative/ medical | National/state | 1 |
| Activity level | 2 | Chawla, 2014; Nguyen, 2014 | Patient | Increases | Medical | State | 3 |
| COPD severity | 1 | Chawla, 2014 | Patient | Increases | Medical | State | 1 |
| Activity level (increased) | 1 | Nguyen, 2014 | Patient | Decreases | Medical records | State | 3 |
| Gender | 1 | Sharif, 2014 | Patient | Decreases | Administrative | National | 1 |
| Interpersonal level | | | | | | | |
| Respiratory medication; vaccines; new oxygen | 3 | Baker, 2012; Nguyen, 2014; Sharif, 2014 | Patient | Increases | Administrative/ medical | National/state | 3 |
| Use of healthcare services before the index period; Number of past hospitalizations for COPD exacerbation; number of exacerbation incidences treat in outpatient setting; number ICU days at index | 3 | Baker, 2012; Chawla, 2014; Nguyen, 2014 | Patient | Increases | Administrative/ Medical | National/state | 1 |
| Prescriptions (statins); Breathing treatment (example: arformoterol) | 2 | Bollu, 2013; Sharif, 2014 | Patient | Decreases | Administrative | National | 3 |
| Number of hospitalizations; follow up visits | 1 | Sharif, 2014 | Patient | Decreases | Administrative | National | 1 |
| Organizational level | | | | | | | |
| LOS; palliative care LOS | 2 | Nguyen, 2014; Sharif, 2014 | Hospital | Increases | Administrative/ medical | National/state | 2 |
| Hospital volume of COPD patients | 1 | Sjoding, 2014 | Hospital | Increases | Administrative | National | 3 |
| Teaching status | 1 | Sjoding, 2014 | Hospital | Increases | Administrative | National | 3 |
| Community level | | | | | | | |
| Patient socioeconomic status | 1 | Sjoding, 2014 | Patient | Increases | Administrative | National | 1 |
| Insurance (example: HMO) | 1 | Baker, 2013 | Patient | Increases | Administrative | National | 2 |
| Insurance (example: dual eligibility, Medicare) | 1 | Moran, 2013 | Patient | Decreases | Medical records | State | 2 |

Modifiability: 1, very difficult to modify; 2, somewhat modifiable; 3, very modifiable. COPD, chronic obstructive pulmonary disease; LOS, length of stay; HMO, Health Maintenance Organization; ICU, intensive care unit; ACA, Affordable Care Act.

**Table 5** Assessment of quality of risk factors identified for readmission after HRRP enactment (2015–2020)

| Risk factor | Number of studies | Articles | Factor level | Impact on readmission | Data type | Geography | Modifiability |
|---|---|---|---|---|---|---|---|
| **Individual level** | | | | | | | |
| Comorbidities (example: heart disease, anemia); number of comorbidities; comorbidity burden; Charlson index | 10 | Candrilli, 2015; Nguyen, 2015; Yu, 2015; Bashir, 2016; Singh, 2016; Lau, 2017; Jacobs, 2018; Spece, 2018; Goto, 2020; Rezaee, 2018 | Patient | Increases | Administrative/ medical records | National/state | 1 |
| Age | 3 | Candrilli, 2015; Simmering, 2016; Stallings-Smith, 2019 | Patient | Increases | Administrative | National/state | 1 |
| COPD severity or complexity | 2 | Candrilli, 2015; Yu, 2015 | Patient | Increases | Administrative | National | 1 |
| Activity level (low) | 1 | Nguyen, 2015 | Patient | Increases | Medical records | State | 3 |
| Gender (male) | 1 | Bashir, 2016 | Patient | Increases | Medical records | State | 1 |
| Comorbidities (example: cancer); number of comorbidities | 2 | Candrilli, 2015; Lin, 2020 | Patient | Decreases | Administrative | National/state | 1 |
| COPD severity or complexity | 1 | Candrilli, 2015 | Patient | Decreases | Administrative | National | 1 |
| Race/Ethnicity | 1 | Nastars, 2019 | Patient | Decreases | Administrative | National | 1 |
| **Interpersonal level** | | | | | | | |
| Respiratory medication (example: inhaled steroids); oxygen prescription; oral corticosteroids at discharge; short acting muscarinic; outpatient medication (example: albuterol) | 4 | Coughlin, 2015; Nguyen, 2015; Roberts, 2015; Rezaee, 2018 | Patient | Increases | Administrative/ medical records | National/state | 3 |
| Use of healthcare services before the index period; ED/observational stay before readmission; previous hospitalizations in 1 year | 3 | Nguyen, 2015; Roberts, 2015; Bashir, 2016 | Patient | Increases | Administrative/ medical records | National/State | 1 |
| Respiratory medication (example: inhaled steroids); discharge medication; roflumilast | 5 | Coughlin, 2015; Roberts, 2015; Qing, 2016; Keshishian, 2019; Roberts, 2020 | Patient | Decreases | Administrative/ medical records | National/state | 3 |
| **Organizational level** | | | | | | | |
| LOS (longer) | 4 | Candrilli, 2015; Nguyen, 2015; Rinne 2017; Jacobs, 2018 | Hospital | Increases | Administrative/ medical records | National/state | 2 |
| Hospital characteristics (hospital tobacco services) | 1 | Stallings-Smith, 2019 | Hospital | Increases | Administrative | National | 2 |
| HHI | 1 | Stallings-Smith, 2019 | Community | Increases | Administrative | National | 2 |
| Better hospital staff responsiveness | 1 | Yang, 2018 | Hospital | Decreases | Administrative | National | 3 |
| Hospital characteristics (example: number of beds, teaching hospitals) | 1 | Stallings-Smith, 2019 | Hospital | Decreases | Administrative | National | 1 |

**Table 5** (*continued*)

**Table 5** (*continued*)

| Risk factor | Number of studies | Articles | Factor level | Impact on readmission | Data type | Geography | Modifiability |
|---|---|---|---|---|---|---|---|
| Community level | | | | | | | |
| Discharge location (example: SNF) | 4 | Shah, 2015; Bashir, 2016; Simmering, 2016; Jacobs, 2018 | Hospital | Increases | Administrative/ medical records | State | 2 |
| Patient socioeconomic status | 3 | Stallings-Smith, 2019; Jacobs, 2018; Goto, 2020 | Patient | Increases | Administrative | National | 1 |
| Insurance (example: Medicare, dually enrolled) | 2 | Shah, 2015; Jacobs, 2018 | Patient | Increases | Administrative | National/state | 2 |
| Discharge location (example: hospice) | 1 | Nguyen, 2015 | Hospital | Decreases | Medical records | State | 2 |
| Partial/Full smoke free policy | 1 | Stallings-Smith, 2019 | Hospital | Decreases | Administrative | National | 3 |
| County characteristics (example: entropy index, age, education) | 1 | Stallings-Smith, 2019 | Patient | Decreases | Administrative | National | 1 |

Modifiability: 1, very difficult to modify; 2, somewhat modifiable; 3, very modifiable. LOS, length of stay; SNF, skilled nursing facility; ED, emergency department; COPD, chronic obstructive pulmonary disease; HHI, Herfindahl-Hirschman Index; HRRP, Hospital Readmissions Reduction Program.

studies examining comorbidities, four examined CCI as a risk factor, among others, to readmission. The CCI is a weighted measure predicting mortality risk one year post hospitalization for nineteen various comorbid condition (45). Two studies found an association between higher CCI scores and increased risk of readmission (40,44) and two studies did not find CCI to be a predictor of readmission (34,36).

Other individual risk factors such as gender, age, and physical activity level were examined in both periods, but to a lesser degree than comorbidities. One study in the 2010–2014-time frame found females to be at a decreased risk for readmission (32). Likewise, one study from the 2015–2020 time frame found males to be at increased risk for readmission (36). While no studies from the 2010–2014 period examined age, three studies during the 2015–2020 period identified age as a risk factor for increased readmission (44,46,47). Two studies from the 2010–2014 period found that lower/higher patient activity level was associated with increased/decreased risk for readmission (28,31), while one study from the 2015–2020 period examined physical activity level (low) as a risk factor for higher readmission rates (34). Additionally, only one study from the 2015–2020 period identified race/ ethnicity (Hispanic and African American) as risk factors for readmission (48). Lastly, increased/decreased COPD severity was identified as a risk factor for increased/ decreased readmission by three studies, one published in 2010–2014 and two in the 2015–2020 timeframe (28,35,44).

### Interpersonal-level risk factors

Two interpersonal risk factors were identified in the literature as being associated with the risk of readmission for COPD, regardless of the time frame. Firstly, variations of the use of healthcare services before the index admission, such as intensive care unit (ICU) days, outpatient treatment, emergency department/room observations, and past hospitalizations were identified as risk factors for readmission among COPD patients, both in three articles published in 2010–2014 (27,28,31) and three articles published in 2015–2020 (34,36,49). Conversely, one study in 2010–2014 found that the number of hospitalizations and follow-up visits decreased the risk of readmission (32).

Secondly, the type of medication or treatment patients received, either as an outpatient or prescriptions at discharge, were identified as important risk factors, but results were mixed. Depending on the type of medication that was administered, readmission rates for COPD patients were either higher or lower. Three 2010–2014 studies identified medication or vaccines increasing the risk of readmission (27,31,32), while two other studies identified statin prescriptions and arformoterol breathing treatments as decreasing the risk of readmission (32,50). Similarly, four studies from 2015–2020 time period identified a variety of medications as risk factors that increased the risk of readmission (34,42,49,51), while other medications were associated with a decreased risk of readmission (49,51-54).

*Organizational-level risk factors*

Across the board, in both time frames, increased LOS was identified by six studies as an important risk factor for increased readmissions (31,32,34,39,44,55). Additionally, the volume of COPD patients and teaching status were found to be statistically significant factors associated with a higher risk of COPD readmission (33). Similarly, one study conducted in the 2015–2020 time frame identified mixed results in hospital-level risk factors associated with readmission risk—with characteristics such as hospital tobacco services found to be associated with increased readmission risk, and the number of beds and teaching hospital status associated with decreased readmission risk (47). Teaching hospitals are defined in the American Hospital Association Annual Survey as hospitals that report having full time equivalent residents and report having a ratio of intern and residents to beds that is more than 0 (56) as they serve to educate and train interns and residents, conduct research, and provide specialized care, among other functions (57). Another study conducted in the 2015–2020 time frame found that better hospital staff responsiveness was associated with a decreased risk of readmission for COPD (26).

*Community-level risk factors*

Lower socioeconomic status across studies was identified as a risk factor for increased readmission rates. One article from the 2010–2014 period (33) and three articles from the 2015–2020 period (39,41,47) studied its impact. Additionally, different types of insurance plans were found to increase the risk of readmission: health maintenance organization plan (27), Medicare & Medicaid dual enrollment (58), and Medicare (39). The degree of competition in the market (Herfindahl-Hirschman Index) was found to be associated with increased readmission risk (47). The Herfindahl-Hirschman Index (HHI) is useful in determining hospitals' share of the market by examining a hospital's number of staffed beds against all staffed beds within the market, and ranges from 0 to 1 in which a score of 1 is indicative of a completely monopolistic market (59). Although no 2010–2014 studies examined discharge location as a readmission risk factor for COPD patients, it was examined amongst five 2015–2020 articles. For the most part, discharge to a skilled nursing facility was identified as a risk factor for readmission (36,39,46,58), while discharge to hospice was associated with decreased readmission (34). Another 2015–2020 article identified county characteristics such as entropy index (a

measure indicative of the degree of racial/ethnic diversity in a community), age, and education as risk factors associated with decreased risk of readmission (47). Only one article examined the effectiveness of full or partial smoke-free implemented policies in counties and found that counties with full or partial policies were associated with a lower risk of readmissions for COPD (47).

## Discussion

This systematic review highlighted several distinct similarities and differences between COPD readmission risk factors pre- and post-inclusion of COPD as an HRRP readmission measure. Comorbidities remained the most explored risk factor of COPD readmissions after 2015, but slight differences in the types of comorbidities assessed were brought to light. Most pre-HRRP articles focused on diseases such as cancer, heart failure, and renal disease, while post-HRRP studies were more likely to include mental health comorbidities such as depression, anxiety, and alcohol and drug abuse (37,38). These changes are important to not only treating COPD patients, but targeting their overall health as COPD patients with depression and anxiety suffer from higher mortality, more exacerbations, and decreased quality of life (60).

Another difference involves the inclusion of discharge location as a COPD readmission risk factor among post-HRRP studies. In general, these studies found that discharge to a skilled nursing facility increased the risk of readmission for COPD patients (36,39,58). Skilled nursing facilities have long been documented as discharge sites for Medicare beneficiaries associated with high readmission rates, most of which are preventable (61). Some research has indicated a hospital-skilled nursing facility readmission review process has aided in the transition from the hospital (62), but future research should continue to examine the impact of discharge location as a risk factor for COPD patient readmission and continue to explore avenues with which to support skilled nursing facilities.

The literature examined highlighted mixed findings as it pertains to medications or breathing treatments received and their association with lower or higher risk for readmission. However, some of these differences may be due to when medications are prescribed, which may lend to how frequently they are used by the patient. For instance, the use of short-acting muscarinic antagonists (SAMA) before admission were found to be associated with a higher readmission rate (49), but another study found

that patients without a SAMA medication within 30 days of being discharged from the hospital had a lower risk of readmission (32). Similarly, oral corticosteroids given before admission were associated with a higher risk of readmission while oral corticosteroids given at discharge were associated with a lower risk of readmission (49). As such, perhaps patients given medication before admission are at a point where their illness is more severe and the medication is not as effective, that is why readmission is more likely. Whereas, once they have intensively been treated at the hospital and their symptoms have improved, these medications are more effective post discharge in their aftercare. In fact, outpatient prescriptions such as albuterol and others were found to be associated with a higher risk of readmission (42), whereas early treatments for roflumilast have been associated with lower readmission risk (54).

The use of breathing treatments such as arformoterol was consistently associated with lower COPD readmission risk (53), even when compared to nebulized short-acting beta antagonists (SABA) (50). Moreover, the use of long-acting muscarinic receptor antagonist (LAMA) therapy was also consistently associated with lower risk of readmission (32,52). Conversely, the use of steroids was more mixed within the literature with inhaled steroids (51) and systemic corticosteroids (31) being associated with lower readmission risk and bronchodilator corticosteroids being associated with higher readmission risk (27). These findings suggest that future research should continue to assess the effectiveness of breathing and medication treatment options in treating and reducing the risk of COPD readmission in order to allow more effective options to be prioritized during COPD treatments instead of lesser effective options and ultimately decrease readmission rates.

Overall, we observed several similarities and differences in risk factors for COPD-related readmissions pre and post HRRP. At the individual level, in most of the literature, comorbidities remained a risk factor that increased COPD readmission across both pre and post HRRP studies. However, post-HRRP studies examined comorbidities through a more complex lens, in that they not only examined the types of comorbidities, but the number of comorbidities, comorbidity burden, and examined the Charlson Comorbidity Index. Similarly, factors such as higher COPD severity/complexity, low activity levels, and male gender were identified in both the pre and post HRRP literature as risk factors that increase COPD readmission. As opposed to pre HRRP studies, some post HRRP studies examined factors such as age and race and ethnicity and

their relation to increased risk of COPD readmission, suggesting that the literature may be shifting toward identifying the roles that sociodemographic disparities may play in COPD readmissions. While age produced mixed results in post HRRP studies, those of a Hispanic or African American race were at a lower risk of COPD readmission.

The COPD readmission risk factors examined at the interpersonal level, for the most part, did not change across pre and post HRRP studies. Across both pre and post HRRP studies, factors such as past use of hospital services and prior admissions/hospitalizations are associated with an increased risk of COPD readmission. Similarly, both pre and post HRRP studies examined respiratory medications and their association with increased or decreased risk of COPD readmissions, and as mentioned previously, findings were mixed across both pre and post HRRP studies depending on the type of medication or breathing treatment administered to the patient. These findings are reflective of the chronic and cyclical nature of COPD, as well as the trial-and-error process with which treating physicians may be trying to identify the best medication possible for an individual to treat their COPD and prevent exacerbations leading to hospitalizations.

At the organizational level, a longer LOS was associated with an increased risk for COPD readmission across both pre- and post-HRRP studies. This may have been indicative of a greater complexity or severity of COPD exacerbation. Among pre HRRP studies, hospital volume of COPD patients was also a factor that increased the risk for readmission. Although teaching status was a risk factor examined among both pre and post HRRP studies, the findings differ with respect to whether it is associated with increased or decreased readmissions as the post HRRP study examined the number of teaching hospitals as a factor (decreased risk), not just teaching hospital status (increased). Among post HRRP literature, a wider variety of organizational level characteristics were investigated. This included tobacco services offered by the hospital and higher competition in the market, which were both associated with an increased risk of readmission. Conversely, hospitals with better staff responsiveness were associated with a decreased risk for readmission.

At the community level, risk factors examined in post HRRP studies have broadened in scope as compared to pre HRRP studies. Across both pre and post HRRP studies, patient socioeconomic status was found to be associated with an increased risk for readmission. Similarly, types of insurance were found to be risk factors in both pre and post

HRRP studies, however, findings differed. Within the pre HRRP literature, insurances such as HMOs were associated with an increased readmission risk while Medicare or Medicare/Medicaid dual eligibility were associated with a decreased risk. However, within post HRRP literature, Medicare or Medicare/Medicaid dual eligibility were associated with an increased risk. Post HRRP studies found that a discharge to a skilled nursing facility is associated with a higher risk for readmission, while a discharge to hospice is associated with a lower risk for readmission. Other factors such as having a partial or full smoke free policy and county factors such as entropy index were associated with lower risks for readmission.

As it pertains to the Ecological Model, an assessment of the different types of risk factors included in each level (*Tables 4,5*) overall shows improvement in more comprehensively addressing the Ecological Model levels. For instance, among the 2010–2014 studies, there were 5 risk factor types addressed at the individual level, 4 at the interpersonal, 3 at the organizational, and 3 at the community level. Among 2015–2020 studies, there were 8 risk factor types addressed at the individual level, 3 at the interpersonal, 5 at the organizational, and 6 at the community level. Even so, these findings also highlight opportunities to assess more COPD readmission risk factors, particularly at the interpersonal level.

Likewise, risk factor modifiability levels included in this review are crucial aspects to consider in the overall goal of decreasing COPD readmissions. They may provide insights to organizations such as hospitals or practitioners such as primary care doctors as to what risk factors they can devote resources toward addressing—that is, prioritizing addressing risk factors with a modifiability level of 3 (very modifiable) and risk factors with modifiability of 2 (somewhat modifiable). That is not to say that risk factors with a modifiability level of 1 (very difficult to modify) should be ignored, but that resources and time may be better spent by first addressing those factors that are within the capacity of hospitals/providers/patients to readily change. For example, the risk factor of activity level (modifiability of 3) appeared in both 2010–2014 and 2015–2020 studies as both a factor that could increase (low level) and decrease (high level of activity) the risk of readmission. This is a risk factor that could be modified by advocating for the importance of physicians to educate and empower their patients toward recognizing the importance of increasing their activity level to better improve their health.

## Limitations

*Limitations*

As explained in the article inclusion criteria, this literature review assumes that articles published 2015–2020, regardless of what year data they examined, have been influenced by the HRRP program either through their literature search, data used, or the publication process. As such, unless specified that the readmission was calculated differently than HRRP, these articles were included. Therefore, it is possible that some articles included in the 2015–2020-time frame should be excluded. Additionally, the scope of the review may be limited by the search terms utilized, including the snowballing methodology used to identify risk factors. It is possible that adopting a broader array of search terms would have produced more studies to consider in this review. With regard to 2015–2020 studies, two (39,41) explicitly stated that CMS HRRP methodology for readmission calculations was followed, while one study utilized CMS HRRP data in its analysis (47). As only three articles fully adhering to CMS' HRRP methodology have been identified and synthesized, it may be difficult to clearly understand or examine the full effect of the introduction of COPD as an HRRP readmission measure on risk factors identified. Future research that examines COPD readmission risk factors using CMS HRRP data may be beneficial as it may provide clearer results to hospital administrators as to what factors are impacting their patients' health and their reimbursement. For example, one observable change that occurred post-COPD implementation is that most 2010–2014 articles conducted 30-, 90-, and 60-day analyses for readmissions, but the majority of 2015–2020 articles examined 30-day all-cause readmission rates. This led to more uniformity in how risks for readmissions were examined and allowed administrators to target 30-day readmission risks more specifically as opposed to 60 and day readmission risks. Lastly, there is potential for selection bias as only one reviewer independently examined the articles against inclusion and exclusion criteria.

## Conclusions

This systematic review has highlighted differences and similarities between risk factors for COPD readmission pre-and-post the introduction of COPD as an HRRP measure. This is the first systematic review to examine U.S.-specific readmission risk factors for COPD patients. However, further research may be necessary to fully assess

these differences in greater detail as more studies begin to utilize CMS HRRP data or apply CMS' methodology to calculating readmission. Additionally, identifying specific risk factors related to COPD readmission would be helpful to physicians in settings across the care continuum as patient health is dynamic and constantly evolving—and care provided at each health encounter affects the next, requiring that efforts to mitigate risk factors for readmission be implemented in a variety of settings.

## Footnote

*Reporting Checklist:* The authors have completed the PRISMA reporting checklist. Available at https://jhmhp. amegroups.com/article/view/10.21037/jhmhp-22-41/rc

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**Table S1** Descriptive summary of literature: 2010–2014

| Year | First author | Study design | Sample size | Risk factors | | Outcome | Risk adjusted |
|------|-------------|--------------|-------------|--------------|--------------|---------|---------------|
| | | | | Increase | Decrease | | |
| 2012 | Nantsupawat | Retrospective cohort | 81 patients | Comorbidities (coronary artery disease & unilateral infiltrate) | | 30-day all cause readmission | No |
| 2013 | Baker | Retrospective cohort | 6,095 patients | 30- & 90-day: comorbidities (liver disease, metastatic tumor, heart failure, diabetes); number ICU days during index; pre-index hospitalization (2/+). 90-day: comorbidities (renal disease, myocardial infarction, malignancy); insurance (HMO *vs.* comprehensive); at least 1 pre-index hospitalization; ED visits (2/+) pre index; number ICU days in index; medication (systemic corticosteroids) | | 30- & 90-day all cause readmission | No |
| | | | | 30 & 90-day: Pre-index hospitalization (2/+); comorbidities (liver disease & metastatic tumor); at least 1 pre-index hospitalization; number ICU days at index. 30-day: comorbidities (chronic pulmonary disease)'. 90-day: insurance (HMO); medication (bronchodilator corticosteroids); outpatient visits pre index (2/+) | | 30- & 90-day COPD (primary/secondary diagnosis) readmission | |
| 2013 | Bollu | Retrospective cohort | 2,463 patients | | Treatment (arformoterol *vs.* nebulized short-acting beta agonists); APR DRG severity (major & extreme) | 30-day all cause readmission | Yes |
| 2013 | Moran | Retrospective cohort | 1,214 patients | Comorbidity (diabetes); social services referral | Cellulitis; insurance status (private & uninsured) | 30-day all cause readmission | No |
| | | | | Comorbidities (anemia & airway disease); social services referral | Insurance status (Medicare & Medicaid, Medicare, Medicare & private, uninsured, private) | 30-day same cause readmission | |
| 2014 | Chawla | Cohort | 54 patients | Higher MRC dyspnea; 1/+ exacerbations in past year; 2/+ hospitalization for exacerbation in past year; 2/+ outpatient treatment for exacerbation in past year; chronic renal disease; 1/+ days outside of house 1 week before hospitalization | | 30-day all cause readmission | No |
| 2014 | Nguyen | Retrospective cohort | 4,596 patients | Pneumococcal vaccine; systemic corticosteroids; new oxygen after index admission; previous hospitalization (COPD and non-COPD related); Charlson index (3+); comorbidity (anemia); palliative care LOS (1-46, 7-13, 14/+); ED or observational stay; discharge location (other than home, hospice or post acute/hospital) | Physical activity (1-149-minute walk per week, 150 or more-minute walk per week; discharge location (hospice) | 30-day all cause readmission | Yes |
| 2014 | Sharif | Retrospective cohort | 8,263 patients | Patient factors: comorbidities (heart failure, lung cancer, anxiety, depression, osteoporosis). System factors: LOS (1-2 & 7+ *vs.* 3-4 days); | Patient factors: sex (female). Provider factors: prescriptions 1 year before index (ACE inhibitor & statins); prescriptions within 30 days of discharge (SABA/SAMA, oral steroid, antibiotic). System factors: number of hospitalizations *vs.* 3/+ admissions (0, 1, & 2); follow up visits within 30 days of discharge | 30-day all cause readmission | No |
| 2014 | Sjoding | Retrospective cohort | 3,018 hospitals | Major teaching hospital; many low SES patients; high COPD volume | | 30-day COPD related readmission | Yes |

ICU, Intensive Care Unit; ED, Emergency Department; HMO, Health Maintenance Organization; COPD, Chronic Obstructive Pulmonary Disease; LOS, Length of Stay; MRC, Medical Research Council; APR DRG, All Patient Refined Diagnosis-Related Groups; ACE, angiotensin-converting enzyme; SABA, short-acting β agonist; SAMA, short-acting muscarinic antagonist.

**Table S2** Descriptive summary of literature: 2015–2020

| Year | First author | Study design | Sample size | Risk factors | | Outcome | CMS data or method | Risk adjusted |
|---|---|---|---|---|---|---|---|---|
| | | | | Increase | Decrease | | | |
| 2015 | Candrilli | Retrospective observational | 140,981 patients | 30- & 90-day for all cause & COPD-related readmissions: long LOS, older age, & high comorbidity index. 30 & 90-day: Comorbidities (cancer-not lung, pneumonia, renal failure); severe COPD complexity. 90-day: comorbidity (heart disease) | 30-day: moderate COPD complexity. 30- & 90-day: comorbidities (lung cancer & asthma) | 30- & 90-day all cause readmission | No | No |
| | | | | 30- & 90-day: comorbidities (renal failure & pneumonia); COPD complexity (severe & moderate). 90-day: comorbidity (asthma) | 30- & 90-day: cancer (not lung) | 30- & 90-day COPD-related readmission | | |
| 2015 | Coughlin | Retrospective cohort | 397 patients | | Inhaled antimuscarinic; positive airway pressure therapy | 30-day all cause readmission & mortality composite score | No | Yes |
| | | | | Inhaled steroids | | 30-day all cause readmission | | |
| 2015 | Nguyen | Retrospective cohort | 2,910 patients | Oxygen prescription at discharge, LOS (13+ days). Patients with low mobility (bed bound, able to sit, able to stand); past hospitalization in 1 year; comorbidities (anemia & chronic pain); ED/observational stay prior to readmission but within 30 days or discharge | Discharge location (hospice) | 30-day all cause readmission | No | Yes |
| 2015 | Roberts | Retrospective | 306 patients | Prior hospitalization; All Patient Refined (APR) DRG (3/+). Short acting muscarinic antagonist (SAMA) inhalers preadmission; oral corticosteroids at discharge | Oral corticosteroids at discharge | 30-day all cause readmission | No | Yes |
| | | | | APR DRG (3/+) | Oral corticosteroids at discharge | 90-day all cause readmission | | |
| 2015 | Shah | Retrospective | 26,798,404 inpatient admissions | Medicare & Medicaid dually-enrolled; discharge location (home without home care & SNF) | | 30-day all cause readmission | No | Yes |
| 2015 | Yu | Retrospective | 18,282 patients | Comorbidities (heart failure/heart disease); COPD severity score | | 30-day all cause readmission; 30-day readmission, COPD primary diagnosis; 30-day COPD any diagnosis | No | No |
| 2016 | Bashir | Retrospective case control | 461 patients | Gender (male); discharge location (SNF); 4-6 comorbidities; 4/+ past visits to ER in 6 months | | 30-day all cause readmission | No | Yes |
| 2016 | Qing | Retrospective cohort | 995 patients | | Early roflumilast treatment | 30-, 60-, 90-day all cause readmission | No | Yes |
| | | | | | Early roflumilast treatment | 30-, 60-, 90-day COPD readmission | | |
| 2016 | Simmering | Retrospective | 480 hospitals 17,918,374 patients 28,265,070 visits | Younger age (40-64 vs. 65+); Younger Medicaid patients (vs. older Medicaid); discharge location (home health care); leave against medical advice | | 30-day COPD readmission | No | Yes |
| 2016 | Singh | Retrospective | 80,088 patients | Comorbidities (depression, anxiety, psychosis, alcohol abuse, drug abuse) | | 30-day all cause readmission | No | Yes |
| 2017 | Lau | Retrospective | 597,502 patients | Validation cohort: comorbidities (alcohol abuse & diabetes) | | 30-day COPD readmission | No | No |
| 2017 | Rinne | Retrospective observational | 33,558 patients 130 VA hospitals | Patient LOS (medium & long, with odds increasing) | | 30-day all cause readmission | No | Yes |
| 2018 | Jacobs | Retrospective | 1,055,830 hospitalizations | Patient insurance (Medicaid); household income (low); high comorbidity burden; longer LOS, discharge location: home healthcare & SNF | Older age | 30-day all cause readmission *for AECOPD | Method | Yes |
| 2018 | Rezaee | Retrospective cohort | 1,574 patients | Outpatient prescriptions (albuterol, fluticasone/salmeterol, inhaled steroids, tiotropium); breathing difficulty chief complaint; tests conducted (arterial blood gas & B-type natriuretic peptide) | | 30-day all cause ED readmission, index COPD | No | No |
| | | | | Charlson score; albuterol; previous smoker; high pulse in ED | | 30-day all cause ED readmission, index COPD patients with breathing difficult as chief complaint | | |
| 2018 | Spece | Retrospective cohort | 2,391 VA patients | Charlson index | | 30-day all cause readmission and/or mortality | No | Yes |
| 2018 | Yang | Retrospective | 4,535 hospitals; 3,513 hospitals reported COPD readmission data | | Better staff responsiveness | 30-day COPD readmission | No | Yes |
| 2019 | Keshishian | Retrospective cohort | 7,892 patients | | Arformoterol tartrate (ARF) treatment | 30-day all cause & COPD specific readmission | No | Yes |
| 2019 | Nastars | Retrospective | 298,676 patients | | Race (Hispanic & African American) | 30-day all cause readmission | No | Yes |
| 2019 | Stallings-Smith | Retrospective | 1,788 counties | County characteristics: rurality; poverty; average median age. Hospital characteristics: HHI; number hospitals part of a system; number of hospital tobacco services | Full & partial smoke free policies (vs. none). County characteristics: older age with 4/+ years of college; average percent older females; average entropy index. Hospital characteristics: number of hospital beds, Medicaid percentage, number of teaching hospitals | 30-day all cause readmission | Data | Yes |
| 2020 | Goto | Retrospective cohort | 905 patients | Adding social factors to predictive models improved prediction of readmission risk. Reference & optimized models: Comorbidity (cardiac disease & respiratory); poverty Optimized model: poverty level (optimized model) | | 8-30-day 'Late readmission' | Method | No |
| | | | | Reference & optimized models: comorbidity (heart disease) | | Full 30-day readmission | | |
| 2020 | Lin | Retrospective cohort | 9,982 patients | | Patients with comorbidities (vs. without); 1-3 comorbidities; gender (female); high income; insurance (Medicare & Medicaid) with comorbidities (vs. no comorbidities); female with 1 comorbidity (vs. female with no comorbidities) | 30-day COPD readmission | No | Yes |
| 2020 | Roberts | Retrospective observational | 10,405 patients | | Long-acting muscarinic receptor antagonist (LAMA) therapy | COPD readmission and/or death | No | Yes |

ED, Emergency Department; COPD, chronic obstructive pulmonary disease; LOS, length of stay; SNF, Skilled Nursing Facility; ER, Emergency Room; HHI, Herfindahl-Hirschman Index; APR DRG, All Patient Refined Diagnosis-Related Groups.