Risk Trajectories of Readmission and Death in the First Year after Hospitalization for Chronic Obstructive Pulmonary Disease

Peter K. Lindenauer^{1,2,3*}, Kumar Dharmarajan^{4,5,6*}, Li Qin⁶, Zhenqiu Lin⁶, Andrea S. Gershon^{7,8,9}, and Harlan M. Krumholz^{5,6,10}

¹Institute for Healthcare Delivery and Population Science and ²Department of Medicine, University of Massachusetts Medical School–Baystate, Springfield, Massachusetts; ³Department of Quantitative Health Sciences, University of Massachusetts Medical School, Worcester, Massachusetts; ⁴Clover Health, Jersey City, New Jersey; ⁵Section of Cardiovascular Medicine, Department of Internal Medicine, Yale School of Medicine, New Haven, Connecticut; ⁶Center for Outcomes Research and Evaluation, Yale–New Haven Hospital, New Haven, Connecticut; ⁷Sunnybrook Health Sciences Centre, Toronto, Ontario, Canada; ⁸University of Toronto, Toronto, Ontario, Canada; ⁹Institute for Clinical Evaluative Sciences, Toronto, Ontario, Canada; and ¹⁰Department of Health Policy and Management, Yale University School of Public Health, New Haven, Connecticut

Abstract

Rationale: Characterization of the dynamic nature of posthospital risk in chronic obstructive pulmonary disease (COPD) is needed to provide counseling and plan clinical services.

Objectives: To analyze risk of readmission and death after discharge for COPD among Medicare beneficiaries aged 65 years and older and to determine the association between ventilator support and risk trajectory.

Methods: We computed daily absolute risks of hospital readmission and death for 1 year after discharge for COPD, stratified by ventilator support. We determined the time required for risks to decline by 50% from maximum daily values after discharge and for daily risks to plateau. We compared risks with those found in the general elderly population.

Measurements and Main Results: Among 2,340,637 hospitalizations, the readmission rate at 1 year was 64.2%, including 63.5%, 66.0%, and 64.1% among those receiving

invasive, noninvasive, and no ventilation, respectively. Among 1,283,069 hospitalizations, mortality at 1 year was 26.2%, including 45.7%, 41.8%, and 24.4% among those same respective groups. Daily risk of readmission declined by 50% within 28, 39, and 43 days and plateaued at 46, 54, and 61 days among those receiving invasive, noninvasive, and no ventilation, respectively. Risk of death declined by 50% by 3, 4, and 17 days and plateaued by 21, 18, and 24 days in the same respective groups. Risks of hospitalization and death were significantly higher after discharge for COPD than among the general Medicare population.

Conclusions: Discharge from the hospital is associated with prolonged risks of readmission and death that vary with need for ventilator support. Interventions limited to the first month after discharge may be insufficient to improve longitudinal outcomes.

Keywords: chronic obstructive pulmonary disease; mortality; patient readmission; artificial respiration; noninvasive ventilation

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*Co-first authors.

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Correspondence and requests for reprints should be addressed to Peter K. Lindenauer M.D., M.Sc., Institute for Healthcare Delivery and Population Science, University of Massachusetts Medical School–Baystate, 3601 Main Street, Springfield, MA 01199. E-mail: peter.lindenauer@baystatehealth.org.

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At a Glance Commentary

Scientific Knowledge on the

Subject: Although 30-day readmission and death rates are well characterized in chronic obstructive pulmonary disease, little is known about the dynamic nature of these posthospital risks over the subsequent year. As the United States shifts toward value-based payments, there is a growing need to understand and manage posthospital risk.

What This Study Adds to the

Field: In this analysis of more than 2.3 million admissions for chronic obstructive pulmonary disease among U.S. Medicare beneficiaries, the cumulative risk of readmission in the year after discharge was 64.2%, and the cumulative risk of death was 26.2%. Daily risk of readmission declined more slowly than the risk of death, and 1 year after discharge, the risks of these outcomes remained markedly elevated compared with the general population of elderly individuals, suggesting long-standing effects of acute illness and hospitalization. Although patients who required ventilator support demonstrated higher initial and cumulative risks than those who did not, the risk profiles of those treated with invasive and noninvasive ventilation were similar. These findings highlight the prognostic significance of respiratory failure and suggest the need for additional vigilance and postdischarge support for patients treated with mechanical ventilation.

Chronic obstructive pulmonary disease (COPD) affects more than 16 million individuals in the United States and is the nation's third leading cause of death (1, 2). The annual cost of caring for patients with COPD has been estimated at \$49 billion, a figure driven largely by the cost of treating exacerbations, which lead to more than 1.5 million emergency room visits and 700,000 hospitalizations each year (3, 4).

Recent research has demonstrated that the days and weeks after hospital discharge represent a period of heightened vulnerability for patients, one in which there

is a high risk of readmission—not only because of the condition responsible for the index admission but also because of a variety of related and seemingly unrelated conditions (5–7). This phenomenon has been described as posthospitalization syndrome, which is believed to stem from an array of physiological and psychological insults associated with hospitalization, ranging from sleep deprivation to poor nutrition and lack of physical activity (8, 9). Evidence of this phenomenon in COPD is seen in a 30-day readmission rate of more than 20% and a 30-day mortality rate among Medicare beneficiaries of approximately 8% (10–12).

Although policy makers and, in turn, health systems have generally focused their attention on the first 30 days after hospital discharge, the ongoing shift from fee-for-service toward value-based approaches to payment has stimulated interest in keeping patients with chronic conditions, such as COPD, healthy and out of the hospital over more extended time periods (13–16). Whereas 30-day readmission and death rates after hospitalization are relatively well characterized, little is known about how the risks of readmission and death evolve over a full year after discharge.

Physicians need comprehensive information about these risks to counsel patients about prognosis and to engage in advanced care planning. More broadly, as health systems assume greater responsibility for the health of the populations they serve, having a quantitative picture of the dynamic nature of patient risk over time is needed to allocate resources efficiently by matching care management programs to patient need. With this in mind, we sought to define the risk of readmission and death over the course of one year in a national cohort of Medicare fee-for-service beneficiaries surviving hospitalization for exacerbation of COPD, to assess how these risks varied according to the need for ventilatory support during the index hospitalization, and to compare the risks of readmission and death among patients with COPD with those in the general population of elderly patients.

On the basis of prior research, we anticipated that the risk of readmission would decline more gradually than the risk of death. Furthermore, we hypothesized that, as a proxy for disease severity as well as a marker for exposure to potential harms of intensive care, need for ventilatory

support would identify patients with the greatest risk in the posthospital period. In addition, we expected poorer outcomes for persons receiving invasive ventilation than for those who received noninvasive ventilation.

Methods

Study Sample

We used Medicare standard analytical and denominator files to identify all admissions to acute care hospitals from 2008 to 2014 with a principal diagnosis of COPD or a principal diagnosis of acute respiratory failure combined with a secondary diagnosis of COPD with acute exacerbation. The cohort was defined using International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM), codes identical to those used in the publicly reported COPD readmission and mortality measures (12) (see Table E1 in the online supplement).

We restricted the study to admissions to hospitals among Medicare beneficiaries aged 65 years or older because the eligibility of younger beneficiaries is dependent on disability or end-stage renal disease, limiting representativeness in this subgroup. We excluded patients with in-hospital death, less than 1 year of enrollment in Medicare fee for service in the absence of death, transfer to another acute care facility, or discharge against medical advice. As with the Centers for Medicare & Medicaid Services (CMS) readmission measures, we used all index hospitalizations over the study period to create a cohort for analyses focused on readmission to the hospital. For analyses of mortality, we created a cohort by randomly selecting one hospitalization per patient per year to avoid repeated measurement of patients who died within 1 year of multiple admissions and to approximate the average patient experience.

Using validated ICD-9 procedure codes, we categorized each admission into one of three groups on the basis of their receipt of ventilatory support during the index hospitalization: those who received invasive mechanical ventilation (ICD-9-CM codes 96.70, 96.71, 96.72, and 96.04) (regardless of whether they also received noninvasive ventilation), those treated with noninvasive ventilation (ICD-9-CM code 93.90 and not ICD-9-CM codes 96.70, 96.71,

96.72, and 96.04) who did not receive invasive ventilation, and patients who did not require either invasive or noninvasive ventilatory support (17, 18).

Outcomes

The study outcomes were readmission and death, which were examined separately. For the year after hospitalization for COPD, we identified the occurrence of a first readmission on each day after hospital discharge and the occurrence of death on each day after hospital discharge. Consistent with current CMS reporting and on the basis of previously established methods, we included only readmission to short-term acute care hospitals and excluded planned readmissions (19). We did not consider transfers to other hospitals on the day of discharge (or the next day) to be readmissions. Vital status was determined through the Medicare Master Beneficiary Summary File.

Comparator Population

To compare the risks of readmission and death among patients with COPD with the corresponding risks of hospitalization and death in the general elderly population, we constructed a comparator population using the 2012 Medicare denominator and provider analysis and review files. The Medicare denominator file contains information on beneficiaries' enrollment status in Medicare fee for service, date of birth, and date of death. The Medicare provider analysis and review file contains information on inpatient hospital admissions for enrolled Medicare fee-for-service beneficiaries, including the principal discharge diagnosis and dates of admission and discharge. Our comparator population included all Medicare fee-for-service beneficiaries aged 65 years or older on December 31, 2011, with at least 12 months of enrollment in fee-for-service Medicare in the absence of death.

Trajectories of Risk

Daily risk of readmission and death. We estimated the daily risk of the first readmission to the hospital and death by day after hospitalization for COPD among patients who were treated with invasive mechanical ventilation, those treated with noninvasive ventilation, and those who received no ventilatory support. To visualize the dynamic nature of these risks, we

constructed risk trajectories and identified the length of time required for daily risks of readmission and death to each decline 50% from their maximum value, as has been done previously (5, 20–22).

We also characterized the time required for daily risks of a first readmission and death to stabilize. We operationalized this concept as the number of days it took before the daily change in risk fell by 95% from its maximal daily decline after discharge, a method we have used previously (5, 20–22).

Relative risks of admission and death.

We characterized the degree to which the risks of readmission and death among patients hospitalized for COPD compared with corresponding risks of hospital admission and death in the general population of elderly Medicare beneficiaries. This was done by computing the 1-year cumulative incidence of hospital admissions and death after hospitalizations for COPD and comparing these results with the cumulative incidence of hospitalization and death among all beneficiaries in the Medicare fee-for-service population.

Statistical Analysis

Daily risks of readmission and death. We developed separate survival models for the risk of first readmission to hospital and death after hospitalization for COPD for the three groups of admissions. The analytical approach differed on the basis of the presence or absence of competing risk. In models used to estimate the daily risk of first readmission to the hospital, we considered death before first readmission to the hospital as a competing risk and therefore calculated the subdistribution hazard—an unconditional hazard—that was derived from the cumulative incidence function reported by Fine and Gray and corrects for competing risk (23). This approach allows the estimation of unconditional risk after consideration of competing risks. We censored data at planned readmission (e.g., for elective procedures) or at 1 year after the index hospitalization, whichever occurred first. In models used to estimate the daily risk of death, there was no competing risk, and we censored data at 1 year after the index hospitalization. In the absence of competing risk, we calculated hazard estimates for death using the life table method.

We used Gray's test to compare the cumulative incidence of first hospital readmission and its corresponding hazard across cohorts defined on the basis of need for ventilatory assistance, including those treated with invasive mechanical ventilation, those treated with noninvasive ventilation, and those who did not require treatment (24). To compare the cumulative incidence of death and its corresponding hazard across the cohorts, we used the log-rank test. We used the bootstrap method with 2,000 iterations to construct 95% confidence intervals for the time required for the daily risks of first readmission to the hospital and death to decline 50% from their maximum hazards after discharge for each of the three ventilation groups.

To characterize the daily change in risk of first readmission to hospital and death with time after hospital discharge, we calculated differences in kernel-smoothed hazard estimates between each day and the preceding day. For each day after the maximum hazard, we divided the daily change in risk by its maximum daily decline after discharge. We used the bootstrap method with 500 iterations to construct 95% confidence intervals for the number of days required for the daily change in risk to decline 95% from its maximum daily decline after discharge.

Relative risks of admission and death.

We calculated the 1-year cumulative incidence of hospital admission and the 1-year cumulative incidence of death among all beneficiaries in the Medicare fee-for-service comparator population in 2012. We prorated these results by day and compared them with the cumulative incidence of hospital readmission and cumulative incidence of death by day (1–365) after discharge from index hospitalization for the three COPD patient subgroups. This was accomplished by calculating the relative risk of hospital admission and death between ventilation groups and the Medicare fee-for-service comparator population over the first 30, 60, 90, 180, and 365 days after discharge.

To make the study and comparator populations more similar, we directly standardized cumulative incidence by age, sex, and race. We used three age categories (65–74, 75–84, and ≥ 85 yr), two sex categories, and three race categories (white, black, and other). We used the Fine and Gray method (23) to derive

Table 1. Characteristics of Patients Hospitalized for Exacerbations of Chronic Obstructive Pulmonary Disease in the Readmission and Mortality Cohorts

Characteristic	Readmission				Death			
	All	No Ventilator Support	Noninvasive Ventilation	Invasive Ventilation	All	No Ventilation Support	Noninvasive Ventilation	Invasive Ventilation
Admissions, <i>n</i> (%)	2,340,637	2,086,915 (89.1)	147,109 (6.3)	106,613 (4.6)	1,283,069	1,162,357 (90.6)	64,971 (5.1)	55,741 (4.3)
Age, yr, mean (SD)	76.3 (7.5)	76.5 (7.5)	75.1 (7.2)	74.1 (6.8)	76.7 (7.8)	76.8 (7.8)	75.6 (7.7)	74.4 (7.1)
Female sex, %	56.1	56.3	55.1	53.9	56.1	56.3	55.1	53.9
Race, %								
White	87.9	88.2	85.4	83.7	87.9	88.2	85.4	83.7
Black	8.7	8.3	10.9	12.4	8.7	8.3	10.9	12.4
Other	3.5	3.4	3.8	3.9	3.5	3.4	3.8	3.9
Comorbidity, %								
Coronary atherosclerosis/angina	53.1	53.0	53.2	54.9	49.2	49.2	48.6	50.6
History of pneumonia	52.0	50.8	58.5	67.1	45.3	44.2	51.2	61.6
Iron deficiency or other unspecified anemias and blood disease	48.4	47.5	54.9	56.5	42.9	42.2	48.0	50.4
Congestive heart failure	45.4	44.1	55.9	55.3	37.4	36.4	46.6	47.0
Diabetes	42.6	41.8	48.7	49.1	39.5	38.9	45.0	45.7
Vascular or circulatory disease	41.9	41.5	44.8	44.8	37.6	37.4	39.9	39.8
Depression	24.6	24.4	28.7	23.2	20.1	20.1	22.5	18.1
Renal failure	23.8	23.0	29.0	30.5	20.6	20.1	25.6	27.2
Dementia or other specified brain disorders	17.7	17.6	19.2	18.5	17.4	17.3	18.8	17.5
Sleep apnea	15.7	14.4	30.4	21.1	13.1	12.1	26.7	17.1
History of mechanical ventilation	10.2	7.6	32.5	29.3	5.4	4.0	18.5	18.5
Malnutrition	9.6	8.8	13.4	21.1	8.0	7.2	11.7	19.7
1-yr mortality rate					26.2	24.4	41.8	45.7
1-yr hospitalization rate	64.2	64.1	66.0	63.5				

the cumulative incidence function of first readmission to hospital for each age–sex–race stratum in the invasive, noninvasive, and no-ventilation cohorts. We derived the cumulative incidence of death for each age–sex–race stratum using the life table method. All analyses were conducted using SAS 9.3 software (SAS Institute).

Results

For readmission analyses, our cohort included 2,340,637 hospital admissions for COPD surviving to discharge, including 106,613 patients who received invasive ventilation, 147,109 who were treated with noninvasive ventilation, and 2,086,915 who did not require ventilatory support. The mortality cohort included 1,283,069 admissions. Figure E1 shows the reasons for excluding hospitalizations. The comparator population of Medicare fee-for-service beneficiaries included 23,052,575 people. Table 1 lists the characteristics of the study cohorts and subgroups. Notably, within the readmission cohort, the mean age was 76 years, 56% were female, and 87.9% were white. There was a high comorbidity

burden, with coronary artery disease, history of pneumonia, and anemia among the most common.

Within 1 year of discharge, readmission to the hospital occurred in 64.2% of patients, including 63.5% of patients who required invasive mechanical ventilation, 66.0% of patients who were treated with noninvasive ventilation, and 64.1% of patients who were treated without ventilatory support. Overall,

26.2% of patients died within 1 year of discharge, including 45.7% of patients who required invasive mechanical ventilation, 41.8% of patients who were treated with noninvasive ventilation, and 24.4% of patients who did not receive ventilatory support. By contrast, among the general Medicare fee-for-service population, the 1-year risk of admission was 19.7%, and the 1-year risk of death was 5.6%

Table 2. Representative Time Points Describing Trajectories of Risk after Hospitalization for Chronic Obstructive Pulmonary Disease among Patients Who Received Invasive, Noninvasive, or No Ventilatory Support

Type of Ventilator Support	Days of Highest Risk	Mean Days for Risk Level to Decline by 50% (95% CI)	Mean Days for Daily Change in Risk to Decline by 95% (95% CI)
No ventilator support			
First readmission	2	43 (43–44)	61 (7–95)
Death	4	17 (14–24)	24 (15–55)
Noninvasive ventilation			
First readmission	2	39 (37–41)	54 (6–117)
Death	3	4 (3–4)	18 (13–37)
Invasive ventilation			
First readmission	2	28 (27–29)	46 (32–88)
Death	3	3 (3–4)	21 (14–41)

Definition of abbreviation: CI = confidence interval.

Although the daily risks of rehospitalization and death both declined over time, the decline was slower for readmission than the risk of death. Specifically, 28 days, 39 days, and 43 days were required for hospitalization involving invasive ventilation, noninvasive ventilation, and no ventilator support, respectively, for the risk of first readmission to decline by 50% (Table 2 and Figure 1). In contrast, the risk of death declined by 50% after 3 days, 4 days, and 17 days after hospitalization involving invasive ventilation, noninvasive ventilation, and no ventilator support, respectively (Table 2, Figure 2).

Similarly, the time period for readmission risk to stabilize was greater than the time period for mortality risk to stabilize (Table 2). The daily risk of first readmission stabilized after 46 days, 54 days, and 61 days after hospitalization involving invasive mechanical ventilation, noninvasive ventilation, and no ventilator support, respectively. In contrast, the daily risk of death stabilized after 21 days, 18 days, and 24 days after hospitalization involving invasive mechanical ventilation, noninvasive ventilation, and no ventilator support, respectively. Although the time to stabilization was similar in these three groups, the daily risk of death remained higher for patients receiving invasive mechanical ventilation throughout the entire follow-up period.

Risks after hospitalization were markedly higher among patients after an admission for COPD than among the general Medicare fee-for-service population (Table 3, Figures 3 and 4). Even for patients who did not require ventilator support during hospitalization, the age-sex-race standardized relative risks of hospital admission were higher by a factor of 13.3 within the first 30 days and by a factor of 3.3 within the first year after discharge. The risk of death within the first 30 days was 10.3 times higher, and the risk at 1 year was 4.0 times higher, than among elderly patients who had not experienced hospitalization.

Discussion

In this study of more than 2.3 million hospitalizations for exacerbations of COPD among U.S. Medicare beneficiaries, we have defined the dynamic nature of the risks of readmission and death in the year after hospital discharge, examined how risks vary

Figure 1. Daily risks of first readmission to the hospital for a 1-year period after hospitalization for chronic obstructive pulmonary disease, according to degree of ventilatory support. IMV = invasive mechanical ventilation; NIV = noninvasive ventilation.

according to the degree of ventilatory support required during the initial hospitalization, and compared the long-term outcomes of survivors of COPD hospitalization with those of the general population of Medicare beneficiaries. A key finding of the study is that the risk of adverse events remains high for an extended period after hospitalization and the time required

for the risk of readmission to fall by 50% and ultimately plateau is far longer in both absolute and relative terms compared with the risk of death. We identified distinct trajectories of risk associated with the need for and type of ventilatory support required, with survivors of invasive mechanical ventilation demonstrating the highest initial and cumulative risks of death and the

Figure 2. Daily risks of death for a 1-year period after hospitalization for chronic obstructive pulmonary disease, according to degree of ventilatory support. IMV = invasive mechanical ventilation; NIV = noninvasive ventilation.

Table 3. Relative Risk of Hospital Admission and Death between Patients after Hospitalization for Chronic Obstructive Pulmonary Disease and the General Elderly Population in 2012

	Age-Sex-Race-Standardized Cumulative Incidence Ratio (95% CI), by Day after Discharge							
	Readmission				Death			
	All	No Ventilator Support	Noninvasive Ventilation	Invasive Ventilation	All	No Ventilator Support	Noninvasive Ventilation	Invasive Ventilation
30 d	13.7 (13.6–13.7)	13.3 (13.3–13.4)	16.4 (16.2–16.5)	16.6 (16.4–16.8)	12.6 (12.5–12.7)	10.3 (10.2–10.4)	30.9 (30.3–31.5)	39.2 (38.4–39.9)
60 d	10.2 (10.2–10.2)	10.0 (10.0–10.0)	11.5 (11.4–11.6)	11.7 (11.6–11.8)	9.8 (9.7–9.9)	8.3 (8.3–8.4)	21.4 (21.1–21.8)	26.5 (26.1–26.9)
90 d	8.3 (8.2–8.3)	8.1 (8.1–8.2)	9.0 (9.0–9.1)	9.2 (9.1–9.2)	8.3 (8.2–8.3)	7.2 (7.1–7.2)	16.9 (16.7–17.2)	20.6 (20.3–20.9)
180 d	5.4 (5.4–5.4)	5.4 (5.4–5.4)	5.6 (5.6–5.6)	5.5 (5.5–5.5)	6.0 (6.0–6.0)	5.4 (5.4–5.4)	11.1 (10.9–11.2)	13.1 (12.9–13.2)
365 d	3.3 (3.3–3.3)	3.3 (3.3–3.3)	3.1 (3.1–3.1)	2.7 (2.7–2.7)	4.3 (4.3–4.3)	4.0 (4.0–4.0)	7.2 (7.1–7.2)	8.1 (8.0–8.2)

Definition of abbreviation: CI = confidence interval.

Figure 3. Age-sex-race-adjusted relative risk of readmission in the first year after hospitalization for chronic obstructive pulmonary disease. IMV = invasive mechanical ventilation; NIV = noninvasive ventilation.

fastest risk decay. Finally, compared with elderly Medicare beneficiaries without a history of hospitalization for COPD, the risk of admission is 13- to 16-fold higher 30 days after discharge and remains elevated even 1 year after discharge. Similarly, compared with other Medicare beneficiaries, the risk of death, even 1 year after hospital discharge, remains four to eight times higher. Taken together, these findings

highlight the short- and long-term vulnerability of patients after hospitalization for COPD, particularly among those treated with mechanical ventilation, and suggest that care management interventions limited to a brief period after discharge may be insufficient to improve long-term outcomes.

We previously reported on the development and validation of a measure of 30-day mortality after exacerbation of

COPD for use by the CMS to assess the performance of U.S. hospitals. In that study, we found that within 30 days of admission, approximately 8% of Medicare beneficiaries had died and that mortality rates varied widely between hospitals (12). Using similar data from eight U.S. states, Shah found that 20.2% of admissions for COPD resulted in a rehospitalization within 30 days, with respiratory-related diseases accounting for roughly half of the cases (11). Although these earlier studies provided novel insights regarding the epidemiology of readmission and mortality associated with COPD, they were limited to examining cumulative outcome rates within 30 days of hospitalization. The present study builds on this work in several significant ways by examining the dynamic nature of risk over the first 30 days, by extending the period of follow-up to 1 year, and by investigating differences in risk trajectories associated with receipt of mechanical ventilation.

Several other investigators have reported on long-term outcomes after hospitalization for COPD. For example, in their study of a cohort of 171 patients admitted in 1999 to a single hospital in the Netherlands, Groenewegen and colleagues reported a 1-year mortality rate of 23% and identified age and long-term corticosteroid use as independent predictors of death (25). More recently, García-Sanz and colleagues reported 1- and 5-year mortality rates of 26% and 64% within a sample of 757 patients hospitalized in Spain between 2007 and 2008 (26). Although the mortality rate in our study was somewhat higher than seen in these other cohorts, our analysis differed from earlier reports in that it was limited to patients aged 65 years and older.

Beyond the realm of obstructive lung disease, our study has strong parallels to one by Dharmarajan and colleagues (5), who used similar methodology to describe and compare risk trajectories of elderly patients after hospitalization for acute myocardial infarction, heart failure, and pneumonia. They found that readmission rates at 1 year ranged from 49.9% among patients with acute myocardial infarction to 67.4% in those with heart failure, whereas 1-year mortality ranged from 25.1% for acute myocardial infarction to 35.8% for heart failure. The risk trajectories we observed for patients with COPD with regard to the time needed for risk to decline

Figure 4. Age-sex-race-adjusted relative risk of death in the first year after hospitalization for chronic obstructive pulmonary disease. IMV = invasive mechanical ventilation; NIV = noninvasive ventilation.

by 50% as well as to reach a plateau period of minimal day-to-day change were most similar to those seen among patients with heart failure. This finding suggests that individuals with chronic conditions such as COPD and heart failure may take longer to recover from the insults of hospitalization compared with those without chronic disease.

As we anticipated, patients who received invasive or noninvasive mechanical ventilation were at increased risk of readmission and death compared with patients who did not require ventilatory support. Need for mechanical ventilation is a marker of more advanced lung disease, which is one explanation for the worse outcomes observed in these populations. At the same time, a growing body of evidence has shown that prolonged stays in the ICU, and especially exposure to mechanical ventilation, are associated with impairment in cognition, mental health, and physical function, known as post-ICU syndrome (27–31). Thus, in addition to differences in underlying lung function, this phenomenon may contribute to the worse outcomes observed for persons who received ventilatory support.

However, we also found that risk differences between the subsets of patients requiring invasive and noninvasive ventilatory support were not pronounced. Although daily risks of death and hospital readmission were initially higher among patients undergoing invasive mechanical ventilation than among those who received noninvasive ventilation, risk profiles for these two groups of patients grew almost indistinguishable within a short time. These

findings are similar to those of Plant and colleagues, who found that after 3 months, there was no additional survival advantage to noninvasive ventilation, but our results differ from those of Conti and colleagues, who described large differences in 1-year readmission rates among those treated with invasive and noninvasive ventilation (32, 33). Because we analyzed the outcomes of patients who survived to hospital discharge, our results suggest that much of the comparative advantage of noninvasive ventilation is limited to the period of hospitalization.

Our study has several notable strengths. This is the first study, to our knowledge, of the long-term outcomes of patients hospitalized for COPD in the United States. Beyond simply computing 1-year survival and readmission rates, our approach to analyzing the dynamic nature of risk is novel, providing clinicians and those overseeing care transition programs with greater insight about how patient needs evolve over time. Furthermore, comparing the risks of death and rehospitalization patients face after hospitalization for COPD with those of an age-, sex-, and race-matched cohort of elderly individuals can help patients and providers set realistic goals for prognosis and stimulate advanced care planning. Last, our analysis was conducted with a census sample of more than 2 million traditional Medicare beneficiaries, vastly outnumbering prior studies and contributing to the generalizability of our results.

Our findings should be interpreted in light of several limitations. First, given the very large size of our sample, we used ICD-9-CM codes rather than direct

clinical assessments or physicians' notes to identify patients with COPD. Second, our analysis was restricted to patients aged 65 years and older. Although this group represents the majority of COPD admissions in the United States (34), we caution against extrapolating our finding to younger patients. Third, our analysis of readmission risk was limited to the risk of first readmission, and we did not explore the issue of multiple readmissions. Fourth, our comparator population was constructed using data from a single year that represented the midpoint of our study cohort to minimize bias arising from secular trends in admission and death. If those trends were nonlinear, we may have over- or underestimated the relative risk associated with a COPD hospitalization. Finally, although we investigated heterogeneity in the trajectories of risk related to the need for ventilatory support, there are undoubtedly other clinical factors that may be equally if not more important predictors of outcomes.

In conclusion, the daily risks of readmission and death are dynamic, remain elevated for an extended period after hospital discharge for an exacerbation of COPD, and are strongly associated with the need for ventilatory support. Future work is needed to develop strategies aimed at mitigating these long-term risks, especially among those treated with mechanical ventilation, and using these data to guide discussions and advanced care planning with patients. ■

Author disclosures are available with the text of this article at www.atsjournals.org.

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