Rural Residence and Poverty are Independent Risk Factors for COPD in the United States

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At a glance commentary: *Scientific Knowledge on the subject:* There is increasing awareness of nationwide disparities in COPD, with a recognized need to better understand risks for COPD in rural areas. The COPD National Action Plan recently identified the need to conduct surveys designed to investigate geographic urban-rural differences as a major goal. Existing studies have identified differences in smoking rates as a contributor to urban-rural disparities in COPD, but there is a need to understand individual and community factors that increase the risk for developing COPD amongst the population as a whole and amongst never-smokers.
What this study adds to the field: This is the first study to report individual, community and geographic risk factors for COPD in the United States. The study findings demonstrate that living in a rural community and poverty are independent risk factors for COPD among both ever and never smokers. The study also demonstrates that community use of coal for heating represents an additional risk factor for COPD among never-smokers. These results suggest that future studies and public health initiatives should investigate household and community-level environmental factors that contribute to COPD prevalence in rural parts of the US in order to reduce disparities.

This article has an online data supplement, which is accessible from this issue's table of content online at www.atsjournals.org

ABSTRACT

Rationale: In developing countries, poor and rural areas have a high burden of Chronic Obstructive Pulmonary Disease(COPD), with environmental pollutants and the indoor burning of biomass implicated as potential causal exposures. Less is known about the prevalence of COPD in the United States with respect to urban-rural distribution, poverty, and factors that uniquely contribute to COPD amongst never-smokers.

Objectives: To understand the impact of urban-rural status, poverty and other community factors on COPD prevalence nationwide and amongst never-smokers.

Methods: We studied a nationally representative sample of adults in the National Health Interview Survey(NHIS) 2012-2015, with data linkage between neighborhood data from the U.S. Census's American Community Survey and the National Center for Health Statistics Urban-Rural Classification Scheme. The main outcome was COPD prevalence.

Measurements and Main Results: The prevalence of COPD in poor, rural areas was almost twice that of the overall population(15.4% versus 8.4%). In adjusted models, rural residence(Odds Ratio(OR), 1.23; $p<0.001$) and census level poverty(OR, 1.12; $p=0.012$) were both associated with COPD prevalence, as were indicators of household wealth. Among never-smokers, rural residence was also associated with COPD(OR, 1.34; $p<0.001$), as was neighborhood use of coal for heating(OR, 1.09; $p<0.001$).

Conclusions: In a nationally representative sample, rural residence and poverty were risk factors for COPD, even amongst never-smokers. The use of coal for heating was also a risk factor for COPD among never-smokers. Future disparities research to better understand contributors to COPD development in poor and rural areas, including assessment of heating sources and environmental pollutants, is needed.

INTRODUCTION

Chronic Obstructive Pulmonary Disease (COPD) continues to be a leading cause of morbidity and mortality worldwide(1–3). In the United States smoking remains the strongest risk factor for development of COPD, though international studies suggest that poverty and indoor air pollution from the burning of biomass may contribute to the burden of COPD worldwide, even amongst those who do not smoke(4–6). While significant work has informed our understanding of international COPD prevalence, substantial knowledge gaps exist in understanding factors that contribute to the regional distribution of COPD in the United States, especially for the estimated 20% of COPD that occurs among never-smokers(7, 8). Beyond smoking, other exposures and risk factors that may contribute to COPD development include exposure to indoor and outdoor pollution, and solid fuel (coal and wood) combustion; exposures that are likely to differ between urban and rural areas(8). Rural COPD has become a recent focus of the NIH and CDC, with a disproportionate increase in prevalence and mortality in isolated rural areas(1, 8-9). The COPD National Action Plan also recently identified the development of surveys and targeted studies designed to understand urban-rural differences and environmental disparities in COPD as a major goal(11). However rural individuals in the U.S. still remain understudied compared to their urban counterparts(12). Due to limited research in rural areas it has been difficult to separate the impact of individual factors, and community-level exposures with potential regional variation, in characterizing this COPD disparity in the U.S.(13–15).

We linked publically available datasets to 1) describe the nationwide prevalence of COPD by urban –rural status and community level poverty; 2) determine the impact of community and individual factors including rural residence, community poverty, household heating exposures, and socioeconomic status on COPD prevalence; and 3) describe prevalence

and determine risk factors for COPD among never smokers and current of former smokers. Some of the results from this study have been previously reported in the form of an abstract(16).

METHODS

Data Sources and Study Sample

Data was obtained from the National Health Interview Survey (NHIS) for the years 2012-2015. The NHIS is a cross-sectional household interview survey conducted annually by the National Center for Health Statistics (NCHS). The survey is a multistate probability design that covers all 50 states and the District of Columbia. The survey was chosen as it is designed to be representative of the non-institutionalized population living within the United States. Our study population was limited to adults aged 40 and over, as COPD is a disease of older adults.

In order to evaluate the effect of community factors on COPD prevalence, we linked participants' census tract information to the U.S. Census Bureau's 2015 American Community Survey(ACS) and to the 2013 NCHS Urban-Rural Classification of Counties. Urbanization was assessed using the 2013 NCHS Urban-Rural Classification, which divides counties into six categories: (1) Large metro, central, (2) Large metro, fringe, (3) Medium metro, (4) Small Metro, (5) Micropolitan and (6) Non-Core. Generally large metro fringe is thought to be equivalent to suburban, while large metro central is considered urban(17). The non-metropolitan areas, micropolitan and non-core, are considered rural. These categories were combined for our analysis given that relatively few participants resided in these counties.

Census tract information is restricted and not available in the public-use NHIS Dataset. The NCHS Research Ethics Review Board (ERB) approved data collection from the NHIS to be linked to census tract information in our study. Analysis of de-identified data from the survey is exempt from the federal regulations for the protection of human research participants. The

NCHS ERB approved analysis of restricted data through the NCHS Research Data Center in Hyattsville, MD.

Outcomes

Our primary outcome was a diagnosis of COPD defined by self-report from the NHIS. Participants were labeled as having COPD by answering yes to having COPD, emphysema, or chronic bronchitis. Given the potential for misclassification, sensitivity analyses were performed using the following definitions 1) excluding individuals reporting a current diagnosis of asthma 2) removing chronic bronchitis from our definition of COPD.

Census Level Variables

The American Community Survey was also utilized to gather census level exposures that may increase COPD prevalence; including poverty, occupations associated with lung disease (i.e. agricultural), and household heating sources(18). The 2015 American Community Survey provided the percent of households living below the poverty level in each census tract. We divided census tracts into poor and non-poor, based on a definition of 20% of households residing below the poverty line (19). The ACS also provided data on the primary heating source used by households in each census tract, including the percent of households using solid fuels (coal and wood) for primary heating. Data regarding census level occupation were also available from the ACS, which grouped certain occupations together, such as agriculture and mining.

Participant-Level Variables

The NHIS was utilized to provide information on risk factors for COPD at the individual level, including demographics, region of residence, smoking information, and household income to poverty ratio. Because of missing data on income, multiple imputed income, provided by the

CDC, was used for analyses of household poverty, reported as income to poverty ratio(20). These data are generated by the CDC using multivariate imputation implemented by the module IMPUTE with IVE-ware (www.isr.umich.edu/src/smp/ive) and were analyzed with MI estimate commands(21). Additional socioeconomic variables provided by the NHIS included home ownership, health insurance status and education. Health insurance was utilized as a surrogate for access to healthcare.

Smoking status was obtained from the NHIS with never-smokers defined as participants who reported smoking less than 100 cigarettes in their lifetime. Smoking exposure was captured as smoking duration, the number of smoking years per participant. Smoking duration is a validated predictor of COPD, recently noted to be more accurate and predictive of COPD than pack-years(22).

Statistical Analysis

All analyses utilized the sampling units, survey weights and strata provided by the NHIS. For participant demographics (**Table 1**) the Clopper-Pearson method was utilized to obtain confidence intervals(23). Two primary logistic regression models were performed: (A) crude/bivariate analysis, (B) multivariate models adjusted for age, sex, race/ethnicity, region of residence, smoking duration, community poverty, urban/rural status, census level use of solid fuels in homes, census level data on percentage of inhabitants in occupations associated with lung disease and individual socioeconomic factors. Subgroup analyses were conducted for smokers and never-smokers. Our primary analysis presents the imputed income to poverty ratio as a continuous variable. A separate analysis was performed that categorizes income to poverty ratio into historically utilized thresholds (>2.00, 1.00-2.00, <1.00), presented in an online

supplement (**Table E1**)(24). All analyses were done using STATA 15/SE (College Station, TX). Statistical significance was defined as a P-value less than 0.05.

RESULTS

Population Characteristics

Data from a total of 90,334 adults above the age of 40 collected between 2012 and 2015 were analyzed (**Table 1**). In our dataset 14.9% of participants resided in rural counties. 15.7% of participants resided in poor census tracts. 43.9% of individuals were current or former smokers. Amongst smokers the mean smoking duration was 27.7 years. The estimated national prevalence of COPD, as estimated from our sample, was 8.4% (8.1-8.7), with a prevalence of 4.3% (4.1-4.6) amongst never-smokers and 13.5% (13.0-14.0) amongst current of former smokers. 23.2% of participants with COPD were never-smokers.

Association of Rural Residence and Indicators of Poverty with COPD Prevalence

The prevalence of COPD varied across regions. Overall, we found the highest prevalence of COPD in rural regions at 12.7% (11.8-13.7) with a higher estimated prevalence in rural, poor communities. Specifically, in rural, poor communities the prevalence was 15.7% (14.0-17.7) compared to 12.0% (11.1-13.0) in rural, non-poor communities. The lowest prevalence was seen in non-poor urban communities at 6.1% (5.7-6.6) (**Figure 1**). This pattern was consistent for the subgroup of never-smokers, with an overall COPD prevalence of 4.4% (4.1-4.6), compared to 8.7% (7.1-10.6) in rural, poor communities (**Figure 2**).

Living in a rural tract remained predictive for COPD prevalence even in adjusted models that controlled for region of residence, age, sex, race, smoking status, indicators of household wealth, education, community poverty, health insurance, census level occupational distribution

and solid fuel use (OR 1.23, p<0.001) **(Table 2)**. This association was present amongst never-smokers (OR 1.34, p<0.001) and current or former smokers (OR 1.19, p 0.031) **(Table 3).**

Both individual socioeconomic status and community poverty were associated with COPD prevalence. At an individual level, a 1 unit decrease in the household income to poverty ratio was associated with an 8% increase in the odds of having COPD (p<0.001). Other markers of individual wealth, including a college education and home ownership were also independently protective for COPD. Community poverty was independently associated with COPD (OR 1.12, p 0.012) even after taking into account measures of individual household wealth (**Table 2**).

Association of Region of Residence and Community-Level Exposures with COPD Prevalence.

Residence in the South and Midwest were associated with increased COPD prevalence in our multivariate models (OR 1.20, p 0.003 and OR 1.27, p<0.001 respectively). This relationship persisted for both current or former smokers and never-smokers.

Sold fuel use was reported at the census tract level. Use of solid fuels for heating appeared to be more common in rural census tracts. 0.5% (0.1-0.9) used coal as the primary heating use in rural, poor census tracts as opposed to 0.02 % (0.01-0.03) in non-rural, poor census tracts. In rural, poor tracts 5.6% (3.3-7.8) used wood as the primary heating source, while 0.6% (0.3-0.9) used wood as the primary heating source in non-rural, poor tracts. In the analysis of never-smokers, there was a significant association for coal combustion in multivariate models (OR 1.09, p<0.001), such that a 1% increase in the number of homes using coal as a primary heating source could be linked to a 9% increase in the odds of having COPD, for never-smokers in that census tract. This relationship was unique to never-smokers and was not significant amongst the overall population or in our model of current or former smokers.

In our crude models increases in census level employment in agriculture, construction, or mining occupations were associated with an increased odds of COPD development, though the effect size was relatively small. None of these relationships were significant in our adjusted model (**Table E1**).

Individual Factors

Other individual demographics, including age, smoking duration, and race were associated with a diagnosis of COPD. Black and Hispanic participants were less likely to report a diagnosis of COPD, OR 0.68 ($p<0.001$) and OR 0.49 ($p<0.001$) respectively. Participants with Medicaid insurance (OR 2.76, $p<0.001$) and Medicare (OR 1.83, $p<0.001$) were also more likely to carry a diagnosis of COPD compared to those with private insurance.

DISCUSSION

Our study shows that the greatest burden of COPD in the United States lies in rural areas, with a prevalence of COPD in rural poor communities nearly double the general population. Community and household indicators of poverty were both associated with COPD prevalence. These associations were demonstrated for never-smokers with COPD, as well as current and former smokers. The results of this study demonstrate an urban-rural disparity that is compounded by several socioeconomic factors.

These findings address the research priorities outlined in the COPD National Action Plan and extend recent reports of urban-rural COPD disparities to also include an evaluation of multiple risk factors at the individual, household, and community levels. Our study demonstrates an association that exists between living in a rural environment and the development of COPD, which persists even when controlling for socioeconomic factors, and exposures that are more common in rural areas (heating with solid fuels as well as agricultural and mining

occupations)(25, 26). Poverty and rural residence represent important risk factors that jointly increase the prevalence of COPD. The combined effects of poverty and shifting demographics may partially contribute to the urban-rural disparity characterized in this study. Publications have described a "suburbanization of poverty", in which the highest growth in poverty has occurred in suburban and rural areas(27).

COPD is also a disease that represents exposure to risk factors over a lifetime, risk factors that are often mediated by poverty and geographic exposures. Low income communities have historically had a higher prevalence of people exposed to indoor and outdoor air pollution, poor nutritional status, low birth weight, and childhood respiratory infections; all factors that may be associated with an increased prevalence of COPD and poor lung function(28–31). Lifetime access to care and health education are also likely to contribute to the increased prevalence of COPD in rural and poor areas(32). Our findings suggested that insurance status was associated with COPD prevalence but inferences are limited by the cross sectional nature of the analysis and the fact that insurance status is a complex and imperfect surrogate for access to care, as it also represents age, socioeconomic status and other factors.

Never-smokers with COPD are another important population that is increasing but remains understudied in the United States. Our study was able to evaluate individual and community wide risk factors for COPD in a nationally representative population of never-smokers. Approximately 23% of our participants with COPD were never-smokers, similar to the 20% that has been estimated in prior studies(33). In our analysis many of the risk factors associated with COPD prevalence were similar between never-smokers and participants with a smoking history, with the notable exception that neighborhood-level solid fuel use for heating was associated with increased COPD prevalence among never-smokers. International studies

have suggested that solid fuel combustion may be associated with an increased prevalence of COPD in low and middle income countries, with minimal exposure to tobacco smoke, but some notable studies have had conflicting results(5, 34). There have been few studies to date investigating solid fuel use and COPD development in the U.S., and the studies that have included sites from the United States are limited in their sample of the U.S. population and have not solely focused on never-smokers (35). A Canadian study, with a more comparable population to ours, suggested that the use of solid fuels was a risk factor for COPD amongst women without a smoking history, but not for ever smokers(36). Similarly in our study, while not a significant factor for the population as a whole, the use of coal for heating was strongly associated with a diagnosis of COPD amongst never-smokers. It is possible that solid fuel use has a detrimental effect on the population as a whole, but the impact of household pollution from solid fuel use might be more apparent in the never smokers where exposure to tobacco is not a competing risk factor. Though the overall use of solid fuel was low, our dataset suggests a disproportionate utilization of coal and wood fuel for heating amongst the rural groups. With these results we now demonstrate a risk factor for non-smokers in the United States, that is more common in rural areas(37).

Previous theories have also suggested that the urban-rural disparities for chronic disease in the United States may be related to not only smoking and indoor air pollutants, but occupational and agricultural exposures in these communities(38). COPD prevalence has been linked to both crop farming and coal mining, occupations more common in a rural areas(39). However, our study did not show a significant association between increases in agricultural or mining occupations, at the census level, and COPD prevalence. This analysis was further limited as the American Community Survey groups multiple occupation groups together (including

agriculture, mining, and forestry), constraining our ability to evaluate these exposures individually. Future studies should focus on environmental factors contributing to higher prevalence of COPD amongst rural communities, looking at occupation and household exposures at the individual level rather than the census level to better delineate these effects(40).

Race also proved to be a significant factor in our analysis. Minority groups (Black, Hispanic, and Asian) were less likely to report a diagnosis of COPD in our analysis. This dataset is not able to determine if this was related to susceptibility factors or disparities in screening for COPD amongst different racial groups. Previous studies looking at the association between racial disparities and COPD prevalence have yielded mixed results(41, 42). African Americans have been described to be at increased risk for early onset COPD, however our study focused on older adults and may not have captured this effect(43).

Limitations

There are limitations to our study. One major limitation is that the NHIS relies on a self-reported diagnosis of COPD. Historically COPD has been underreported, with spirometry data estimating that COPD prevalence may be double what is suggested by self-reported data(44). The underreporting of COPD may in fact underestimate the disparities reported in our analyses. The problem of self-report is also not unique to our study and is a limitation of large-scale estimates of COPD prevalence. We did perform multiple sensitivity analyses to limit the risk of misclassification, and in our alternative definitions for COPD the relationships observed between rural residence and COPD persisted (**Table E2**). A limitation to our model of nonsmokers was a lack of information on second hand smoke exposure, and a potential for under reporting of smoking exposure amongst participants. Other household air pollutants and exposures, such as coal use for heating, were also reported at the census tract level rather than for individual

participants with household measurements. This data was also cross-sectional and we were unable to measure other potential risk factors including early childhood infections, geographic mobility, changes in access to care and duration of residence in rural tracts over time. Many of these limitations were countered by having robust data from the NHIS that allowed us to measure individual poverty and markers of socioeconomic status.

Our analysis has several strengths, including the NHIS's careful design, which provides a robust representation of the entire US population. Our dataset allows us to capture individuals living in rural parts of the US, who have remained understudied in clinical research and environmental monitoring campaigns(45, 46). The combination of NHIS and Census data allows us to analyze both community wide and individual factors that contribute to COPD prevalence nationwide. The American Community Survey additionally allowed us to uniquely link robust data on heating practices and occupations to health outcomes. Our use of the NCHS Urban Rural Classification of Counties was an additional strength and provided the ability to move beyond a dichotomized classification of urban versus rural, which previous studies relied on, and distinctly consider suburban, small and medium metropolitan areas (9). In total the large-scale nature of this analysis allows us to investigate the association between rural residency and poverty on COPD throughout the United States.

Overall Conclusions

In a nationally representative sample of the US population, living in a rural area, community poverty, and indicators of household wealth were significant risk factors associated with higher COPD prevalence. Among individuals with COPD that reported never smoking, living in a community with coal use as a primary heating source was an additional risk factor, suggesting that indoor air pollution is a risk factor that is especially relevant for this population.

Future disparities research should focus on designing local cohorts to better understand the unique risk factors within rural and poor populations that contribute to the development of COPD, including environmental monitoring to capture indoor air pollution (such as solid fuel combustion). These research efforts will be essential in developing strategies to reduce the burden of COPD and eliminate disparities in disadvantaged rural populations among both ever and never smokers. While these efforts do not reduce the importance of tobacco cessation initiatives, the answers to these questions can be utilized to develop policy targeted at decreasing the burden of COPD nationwide.

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Rural Residence and Poverty are Independent Risk Factors for COPD in the United States

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Online Data Supplement

TABLE E1. Full model of Individual and Community Level Predictors of COPD with Household Poverty Categorized

	Crude Model			Adjusted Model*		
	Odds Ratio	95% CI	P-Value	Odds Ratio	95% CI	P-Value
Census Tract Characteristics						
Urban-Rural Status						
Urban			Reference			
Suburban	1.04	0.93-1.16	0.51	0.97	0.87-1.07	0.51
Medium Metro	**1.30**	**1.17-1.44**	**<0.001**	1.03	0.93-1.15	0.53
Small Metro	**1.48**	**1.28-1.44**	**<0.001**	1.08	0.93-1.24	0.31
Rural	**2.01**	**1.80-2.23**	**<0.001**	**1.26**	**1.11-1.43**	**<0.001**
Census Level Poverty						
Community Poverty	**1.46**	**1.35-1.57**	**<0.001**	**1.12**	**1.03-1.23**	**0.009**
Regions						
Northeast			Reference			
Midwest	**1.35**	**1.21-1.50**	**<0.001**	**1.22**	**1.09-1.38**	**0.001**
South	**1.32**	**1.19-1.47**	**<0.001**	**1.28**	**1.15-1.42**	**<0.001**
West	**0.87**	**0.78-0.98**	**0.023**	1.01	0.90-1.14	0.87
Census Tract Fuel Use†						
Wood	**1.01**	**1.01-1.02**	**<0.001**	1.00	0.99-1.00	0.23
Coal	**1.07**	**1.04-1.11**	**<0.001**	1.03	0.98-1.08	0.28
Occupation Category‡						
Agriculture, Mining	**1.02**	**1.01-1.03**	**0.002**	1.00	1.00-1.01	0.64
Construction	**1.02**	**1.01-1.03**	**0.001**	1.00	0.99-1.01	0.94
Manufacturing	**1.02**	**1.01-1.02**	**<0.001**	1.00	1.00-1.01	0.131
Individual Characteristics						
Demographics						
Age (per 10 year increase)	**1.32**	**1.29-1.35**	**<0.001**	**1.04**	**1.00-1.07**	**0.039**
Smoking duration	**1.04**	**1.04-1.05**	**<0.001**	**1.04**	**1.03-1.04**	**<0.001**
Race						
White			Reference			
Black	**0.87**	**0.79-0.95**	**0.002**	**0.69**	**0.62-0.77**	**<0.001**
Asian	**0.29**	**0.24-0.36**	**<0.001**	**0.44**	**0.36-0.55**	**<0.001**
Hispanic	**0.47**	**0.42-0.53**	**0.017**	**0.50**	**0.44-0.58**	**<0.001**
Insurance Status						
Private Insurance			Reference			
No Insurance	**1.62**	**1.42-1.84**	**<0.001**	1.10	0.95-1.28	0.189
Medicare	**3.14**	**2.89-3.41**	**<0.001**	**1.89**	**1.70-2.10**	**<0.001**
Medicaid	**5.06**	**4.59-5.58**	**<0.001**	**2.76**	**2.44-3.14**	**<0.001**
Education						
College and Beyond			Reference			
High School Graduate	**1.62**	**1.49-1.75**	**<0.001**	1.09	1.00-1.19	0.061
Less Than High School	**2.13**	**1.96-2.31**	**<0.001**	**1.20**	**1.08-1.32**	**0.001**
Home Ownership Status						
Owns Home			Reference			
Other Arrangement (Rented)	**1.54**	**1.43-1.65**	**<0.001**	**1.20**	**1.11-1.30**	**<0.001**
Household Poverty§						
>2.00			Reference			
<2.00 and ≥1.00	**2.10**	**1.95-2.27**	**<0.001**	**1.32**	**1.21-1.47**	**<0.001**
<1.00	**2.63**	**2.44-2.84**	**<0.001**	**1.41**	**1.27-1.57**	**<0.001**

*Adjusted for urban-rural status, community wealth, region, census level occupational distribution, census level fuel use, race, age, sex, smoking duration, household poverty, home ownership, education, and insurance type

†Per 1% increase in census tract residents using this fuel type as their primary source of heating

‡Per 1% increase in census tract residents employed in this occupation

§ Household Income to Poverty Ratio

Table E2. Sensitivity Analysis For Different Definitions of COPD*

	Original Definition		Excluding Asthma†		Excluding Chronic Bronchitis ‡	
	Odds Ratio (95% CI)	P-Value	Odds Ratio (95% CI)	P-Value	Odds Ratio (95% CI)	P-Value
Urban-Rural Status						
Urban			Reference			
Suburban	0.97 (0.87-1.07)	0.51	0.90 (0.79-1.02)	0.088	1.03 (0.90-1.18)	0.68
Medium Metro	1.02 (0.92-1.14)	0.69	0.96 (0.85-1.09)	0.56	1.07 (0.94-1.23)	0.31
Small Metro	1.05 (0.91-1.21)	0.49	0.97 (0.82-1.14)	0.67	1.16 (0.97-1.39	0.102
Rural	**1.23 (1.09-1.40)**	**<0.001**	**1.16 (1.01-1.33)**	**0.035**	**1.34 (1.14-1.58)**	**<0.001**

*Adjusted for urban-rural status, community and household wealth, region, census level occupational distribution, fuel use, race, age, sex, smoking duration, home ownership, education, and insurance type

†Adjusts original definition of COPD to not include individuals with a current diagnosis of asthma
‡Excludes individuals who only have a diagnosis of chronic bronchitis from having COPD