Neighborhood Disadvantage, Healthcare Utilization, Costs, and Outcomes among U.S. Veterans with COPD

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Abstract

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Among individuals with chronic obstructive pulmonary disease (COPD), neighborhood poverty is associated with increased disease rates and poorer outcomes. The purpose of this thesis was to determine whether neighborhood disadvantage is associated with outpatient healthcare utilization and costs among U.S. veterans with COPD. We used the Area Deprivation Index (ADI) to represent neighborhood disadvantage. Our primary outcomes were total 1-year outpatient utilization and total outpatient costs. In adjusted primary analyses, there was no significant association between ADI and total outpatient utilization, however, residence in a neighborhood in the highest ADI quartile was associated with lower outpatient costs (Average Marginal Effects [AME] = -$192.49; 95% CI: -$314.29, -$70.70). In adjusted secondary analyses, higher ADI was associated with fewer pulmonary visits (AME = -0.14; 95% CI: -0.21, -0.07), lower outpatient encounter costs (AME = -$175.83; 95% CI: -$278.14, -$73.52), and worse clinical outcomes.

BACKGROUND

Social and contextual determinants of health, including the conditions within which people are born, work, live, and age, contribute significantly to health outcomes and well-being.[1] Social determinants can be broadly divided into individual-level and community-level factors. Poverty, a complex and insidious community-level social determinant, often exhibits distinct geographic patterns across the urban to rural continuum.[2] The result is a patchwork of neighborhoods and regions throughout the United States with inequitable health outcomes.[3] Among individuals with chronic obstructive pulmonary disease (COPD), neighborhood-level poverty is associated with increased disease rates, poorer outcomes, and higher disease-specific mortality.[4–6] There are myriad neighborhood inequities that may explain these associations.[7–10] While many are deeply entrenched, some may be modifiable at the health systems level.[11] Access to high-quality healthcare services may represent one such modifiable factor.

Healthcare utilization represents realized access to care within a health care system, while costs reflect service intensity.[12] Utilization depends not only on physical access to and availability of healthcare resources but also on patient perceptions regarding the convenience, affordability, acceptability, and need for health care services.[12,13] Prior research demonstrates that increasing neighborhood poverty is associated with variable healthcare utilization across multiple chronic and acute conditions.[14–16] The association between neighborhood disadvantage and costs is also variable, though prior work in the Medicare population shows that patients with the highest neighborhood disadvantage incurred lower physician-related costs but higher preventable healthcare costs.[14] While data on patients with COPD are limited, researchers from the United Kingdom found that increasing neighborhood poverty was associated with increased emergency health care use, health care costs, and mortality.[17] Understanding how patients from vulnerable

communities interact with the healthcare system may inform how to reallocate resources to better serve high-risk individuals.

Among U.S. veterans with COPD, we performed a cohort study to determine the association of neighborhood socioeconomic disadvantage with subsequent outpatient healthcare utilization and costs. Veterans enrolled in the Veterans Health Administration (VA) for their care represent a unique study population, allowing us to examine outpatient utilization and cost independent of insurance status. We hypothesized that increased neighborhood disadvantage is associated with reduced total outpatient healthcare utilization and lower total outpatient costs, reflecting worse access and lower service intensity. Given prior studies demonstrating that the impact of neighborhood disadvantage on some COPD outcomes is worse for those in rural areas, we analyzed whether rurality modifies the association between neighborhood disadvantage and healthcare utilization and costs.[4] We hypothesized that disparities in utilization and costs would be greater for individuals with rural residence due to healthcare provider and service shortages.

METHODS

Study Design, Data, and Cohort Selection

We conducted a cohort study of veterans who were diagnosed with COPD between January 1, 2010, and December 31, 2018. We defined COPD using a pragmatic, health systems-oriented definition based on two or more outpatient COPD visits in a 12-month period based on *International Statistical Classification of Diseases* (ICD) 9 or 10 code, and either a) at least two dispensations of a maintenance inhaler (long-acting beta agonist, long-acting muscarinic antagonist, or inhaled corticosteroid), or b) at least 6 dispensations of a rescue inhaler (short-acting beta agonist or muscarinic antagonist), or c) outpatient nebulizer therapy within the same 12-month period.[18] We did not require spirometry to confirm airflow obstruction, as patients with

access barriers may be less likely to complete spirometry. We included only patients enrolled in VA-based primary care, as they may be more likely to utilize the VA for their healthcare needs. The index date for entry into the cohort was defined as the earliest date an individual met all entry criteria. We utilized data from the VA Corporate Data Warehouse, which captures information on patient demographics, encounters, ICD-9 and ICD-10 diagnostic codes, and prescriptions. We extracted cost data from the VA Managerial Cost Accounting System (MCA), an activity-based cost allocation system.[19]

Exposure

Our primary exposure was the Area Deprivation Index (ADI), a composite measure of socioeconomic disadvantage at the census block group (CBG) level.[20,21] Census block groups generally contain between 600 and 3,000 people and are the census division that most closely approximates a neighborhood.[20] The ADI includes 17 measures derived from the US Census, including income, education, housing, employment, home and vehicle ownership, and family structure. The ADI reports ranked values from 1 (lowest disadvantage) to 100 (highest disadvantage) and is freely available online. We geolocated patients to the CBG containing their home address latitude and longitude at the time of cohort entry, and CBGs were matched to their respective ADI national ranking. We modeled ADI as a categorical variable based on quartile, with "lowest disadvantage" defined as the first quartile, and "highest disadvantage" defined as the fourth quartile.[22]

Outcomes

The primary outcomes were total outpatient healthcare utilization per patient and total outpatient costs per patient in the 1 year after index date. We defined healthcare utilization as the total count of primary care, pulmonary, cardiology, urgent care, and emergency department encounters. We

included cardiology visits due to high cardiac comorbidities in patients with COPD.[23] We identified visits using VA stop codes, which denote the type of clinical services provided at a given location.[24] We examined cost using a health system-oriented definition as the sum of the cost of outpatient encounters and outpatient medications. Outpatient encounter costs include labor costs as well as laboratory and radiology charges. Outpatient medication costs include all outpatient medication prescriptions. We inflation-adjusted dollar amounts to 2018 dollars using the Consumer Price Index.[25,26]

The secondary outcomes were outpatient utilization by visit type, outpatient costs for encounters and medications, and binary outcomes of death, COPD exacerbation (inpatient or outpatient), and hospitalization for COPD exacerbation. We defined the binary outcomes of COPD exacerbation and hospitalization for COPD exacerbation as composite outcomes that included death to account for the competing risk of death.[27] We identified inpatient COPD exacerbations using a principal discharge diagnosis of COPD or a diagnosis of respiratory failure with a secondary diagnosis of COPD. We defined outpatient COPD exacerbations using ICD 9 and 10 codes with the prescription of an oral steroid or antibiotic within 2 days of the encounter.[27]

Covariates

We selected multiple patient-level covariates *a priori* to adjust for confounding based on previously published work.[27–29] These included age, sex, race/ethnicity, VA service-connected status, VA Priority Group, rurality, drive distance to the nearest VA facility with primary care, body mass index (BMI), smoking status, and the Charlson comorbidity index. VA service-connected status reflects military service-related disability and impacts veteran eligibility for VA benefits and disability compensation.[30] VA service-connectedness and drive distance have been highly associated with healthcare utilization in prior studies.[31,32] We used Veteran's Priority Group as a proxy for

socioeconomic status.[33] VA Priority Group is assigned based on presence and degree of service-related disability, income, eligibility for Medicaid coverage, and receipt of VA pension benefits.[34] Priority Groups 1-3 are primarily based on service-connected disability; groups 4-6 are based on catastrophic disabilities (Priority Group 4), non-service connected disabilities or annual income below a certain poverty threshold (Priority Group 5), and exposure to environmental hazards during deployment (Priority Group 6); and Priority Groups 7-8 are generally assigned to veterans with no service-connected disabilities and who have an annual income over a certain poverty threshold.[34,35] A 2021 survey of veteran enrollees' health and use of health care found that Priority Groups 4-6 were most likely to be uninsured, have Medicaid coverage, and those in Priority Group 5 were most likely to be unemployed.[35] We defined urban versus rural residence based on the VA's "URH" classification system which assigns "urban," "rural," "highly rural," and "isolated" based on Veteran's geocoded home address.[36] We modeled sex, race/ethnicity, VA Priority Group, smoking status, and rurality as categorical variables as they are likely to have a non-linear relationship with the outcome variables. We modeled age, drive distance, service-connected percentage, BMI, and Charlson comorbidity index as continuous variables.

Statistical Analysis

We performed descriptive statistics and compared the balance between patient characteristics using standardized mean differences (SMDs) for both continuous and categorical variables.[37,38] We estimated the association between ADI and 1-year outpatient healthcare utilization using univariable and adjusted multivariable negative binomial regression models. We employed an independent variable offset to account for the length of time individuals were at risk of utilizing healthcare services. For patients who survived the entire year following the index date, this offset was set to 365 days. For patients who died during the follow-up period, the offset was adjusted to reflect the number of days they remained alive in the year. We estimated the association between

ADI and 1-year healthcare costs using both univariable and adjusted multivariable generalized linear models. We assumed a gamma distribution and log link based on results from the modified Park test and Box-Cox test.[39] Given that the likelihood of using health care may be related to the variability in staffing capacity and other factors that may vary across facilities, all models were adjusted for intracluster correlation at the VA facility level using cluster-robust standard errors. The results of all analyses for the utilization and costs were reported as average marginal effects (AMEs) using the STATA 'margins' command.[40] AMEs for utilization represent the change in 1-year encounters per patient associated with exposure to the highest quartile of neighborhood disadvantage. AMEs for cost represent the change in 1-year cost in dollars per patient associated with exposure to the highest quartile of neighborhood disadvantage. We estimated the association between ADI and our secondary outcomes using logistic regression analyses.

We additionally assessed, based on *a priori* hypothesis, whether rurality serves as an effect modifier in the association between ADI and our primary and secondary outcomes. We ran two-way interaction regression analyses with an interaction term between ADI and rural status. We assessed the direction and statistical significance of the interaction term. In sensitivity analyses, we stratified primary and secondary analyses by rural status. We defined statistical significance as $P<0.05$ for main effects and $P<0.10$ for interactions. We performed all statistical analyses using STATA (version 18.0).

RESULTS

Patient Characteristics

In total, we identified 740,251 patients with a diagnosis of COPD between 2010 and 2018. We excluded 236,546 patients who were not enrolled in VA primary care, 6,224 patients who lacked

utilization and cost data, and 42,108 patients who lacked a home address and could not be geolocated to a CBG. The final study cohort consisted of 455,373 patients (Figure 1). Veterans were evenly distributed between quartiles of ADI. Table 1 describes how the veterans in the highest and lowest quartiles of disadvantage compared to the overall population. Notably, veterans in the highest quartile of disadvantage were much more likely to report Black race than the lowest quartile of disadvantage as well as the overall population (overall population: 11%; highest quartile: 16%; lowest quartile: 9%; SMD 0.20). Veterans in the highest quartile of disadvantage were also significantly more likely than the overall population and those in the lowest quartile of disadvantage to be rural (highest quartile: 54%; lowest quartile: 26%; SMD 0.56) and have a longer drive distance to the nearest VA primary care facility (highest quartile: 35.04 miles; lowest quartile: 27.11 miles; SMD -0.23). These results highlight the complex associations between race, rurality, and geographic patterns of disadvantage within the veteran patient population. We also found significant differences in Priority Group between veterans in the highest compared to lowest quartiles of disadvantage (SMD 0.31). Notably, 38.3% of veterans in the highest compared to 27.5% in the lowest quartile were assigned Priority Group 5, which may reflect differences in income and employment between groups. We also examined the clinical characteristics of these patients in the year prior to cohort entry. Veterans from disadvantaged neighborhoods were more likely to be current smokers (highest quartile: 51%; lowest quartile: 38%; SMD -0.09). There were no substantial differences in the number of common chronic conditions or BMI between groups. We found no significant differences in the total number of outpatient encounters, total outpatient costs, or numbers of distinct medications prescribed between veterans in the highest compared to lowest quartiles of disadvantage.

Unadjusted Differences in Outcomes between Neighborhood Disadvantage Groups

The mean 1-year outpatient healthcare utilization was 2.83 (standard deviation [SD] = 3.88) encounters for patients in the most disadvantaged neighborhoods compared with 3.03 (SD = 4.15) encounters among patients in the least disadvantaged neighborhoods. Patients from the most disadvantaged neighborhoods had 0.19 fewer total visits (95% confidence interval [CI]: -0.37, -0.01). Patients from the most disadvantaged neighborhoods had fewer pulmonary encounters (mean = 0.68; SD = 1.37) compared to those from the least disadvantaged neighborhoods (mean = 0.84; SD = 1.70) for a difference of 0.17 (95% CI: -0.24, -0.10) fewer visits. Primary care, cardiology, emergency department, and urgent care utilization were similar between the two groups (Table 2). The mean 1-year outpatient cost was $2,431.28 (SD = $2,747.07) per patient from the most disadvantaged neighborhoods compared with $2,667.52 (SD = $3,226.50) per patient from the least disadvantaged for a difference of $236.10 (91% CI: -$368.15, -$104.05) in lower total costs for veterans from the most disadvantaged neighborhoods. Outpatient encounter costs were lower for patients from the most disadvantaged neighborhoods compared to the least disadvantaged neighborhoods, though medication costs were similar between groups (Table 2).

Multivariable Primary Analyses

In adjusted analyses, the small difference observed in unadjusted analyses of mean 1-year outpatient utilization between patients from the most versus the least disadvantaged neighborhoods was further attenuated (AME = -0.12; 95% CI: -0.29, 0.05) (Table 2). However, residence in a neighborhood with highest disadvantage was associated with lower 1-year outpatient costs (AME = -$192.49; 95% CI: -$314.29, -$70.70).

Multivariable Secondary Analyses

In adjusted analyses, there was no difference in primary care, cardiology, emergency department, or urgent care utilization between patients from the most versus the least disadvantaged

neighborhoods (Figure 2). However, residence in a neighborhood with highest disadvantage was associated with fewer pulmonary visits (AME = -0.14; 95% CI: -0.21, -0.07). There was no difference in medication-related costs, however, higher neighborhood disadvantage was associated with significantly lower outpatient encounter costs (AME = -$175.83; 95% CI: -$278.14, -$73.52).

Adjusted logistic regression models demonstrated that residence in a neighborhood with the highest disadvantage is associated with higher odds of death in 1-year follow-up (OR = 1.07; 95% CI: 1.002, 1.13), higher odds of COPD exacerbation or death (OR = 1.13; 95% CI: 1.06, 1.20), and higher odds of hospitalization for COPD exacerbation or death (OR = 1.09; 95% CI: 1.02, 1.16) (Table 3).

ADI Associations by Rural Status

Table 4 describes how associations between neighborhood disadvantage and utilization and costs vary for urban compared to rural veterans. Rurality did not modify the associations between neighborhood disadvantage and the primary outcomes of total outpatient utilization ($P_{interaction}$=0.15) and total outpatient costs ($P_{interaction}$=0.22). However, among urban veterans, those with highest neighborhood disadvantage had 0.30 (95% CI: -0.57, -0.02) fewer total outpatient visits compared to those with lowest disadvantage, whereas among rural veterans, there was no significant difference in total outpatient utilization (AME_{rural} = -0.02; 95% CI: -0.14, 0.10). In addition, among urban veterans, those from the most disadvantaged neighborhoods had $321.01 (95% CI: -$527.63, -$114.39) lower total outpatient costs compared to those from the least disadvantaged neighborhoods, whereas among rural veterans, there was no significant difference in total outpatient costs. These results indicate that nearly all of the difference in total outpatient utilization in the unadjusted primary analysis and the difference in total outpatient costs in the adjusted primary analysis were due to differences among urban veterans.

For secondary outcome, after adjusting for covariates, the impact of neighborhood disadvantage depended on rural status only for pulmonary utilization ($P_{interaction}$=0.003), outpatient visit costs ($P_{interaction}$=0.05), and outpatient medication costs ($P_{interaction}$=0.07). Among urban patients, residence in a neighborhood with highest disadvantage was associated with 0.24 fewer pulmonary visits (95% CI: -0.35, -0.14) compared to residence in the least disadvantaged neighborhoods. However, there was no significant difference in pulmonary utilization for rural patients from different quartiles of neighborhood disadvantage (AME_{rural} = -0.05; 95% CI: -0.11, 0.01). Urban veterans from the most disadvantaged neighborhoods had $326.07 (95% CI: -$510.13, -$142.00) lower outpatient encounter costs compared to those in the least disadvantaged neighborhoods. There was no significant difference in outpatient encounter costs for rural patients from different quartiles of neighborhood disadvantage (AME_{rural} = -$42.06; 95% CI: -$104.81, $20.68). Taken together, these results indicate that nearly all the differences in pulmonary utilization and outpatient encounter costs observed in adjusted secondary analyses were due to differences among veterans from urban neighborhoods.

DISCUSSION

Among a nationwide cohort of veterans with COPD, we demonstrated that residence in a neighborhood with high socioeconomic disadvantage is not associated with changes in total outpatient utilization but is associated with reduced total outpatient costs. This implies that, despite a similar number of outpatient encounters, these patients may be receiving lower service intensity. Patients from more disadvantaged neighborhoods also had lower pulmonary utilization and increased risk of death, COPD exacerbations, and hospitalization for COPD exacerbations at one-year follow-up. Furthermore, urban patients experienced greater differences in utilization and

costs based on neighborhood disadvantage compared to rural patients, even after adjusting for drive time to care. This suggests that barriers beyond physical proximity may be impacting urban patients' ability to access care. These barriers represent important points of investigation and intervention to improve the quality of care and outcomes for patients from vulnerable communities.

Our work expands on prior studies that demonstrated associations between increased neighborhood disadvantage and worse COPD outcomes.[4,5] Despite increased interest in contextual determinants of health, proposed mechanisms by which neighborhood poverty impacts COPD outcomes remain largely hypothetical. Our study addresses this gap in evidence by demonstrating a potential link between neighborhood disadvantage and reduced utilization of outpatient pulmonary consultation. Consultation with a pulmonologist is associated with higher receipt of guideline concordant care, which is an important determinant of COPD outcomes.[41] Despite similar utilization of primary care, patients in the most disadvantaged neighborhoods had lower utilization of outpatient pulmonary services. This observation may be explained by several factors.

First, these patients may be receiving fewer referrals for pulmonary consultation. Both COPD and increasing neighborhood disadvantage are highly associated with multimorbidity.[9,42] Over-burdened primary care providers may deprioritize COPD care in favor of other chronic disease management, such as cardiovascular disease.[23] However, our cohort had similarly high rates of multimorbidity across low and high neighborhood disadvantage, and our models adjusted for comorbidity. Alternatively, for those Veterans in some high ADI areas, pulmonary referral rates could be reduced due to implicit or explicit bias, which is known to exacerbate heath disparities for marginalized patients.[43] Prior research shows that Black patients receive fewer specialty referrals from primary care providers than White patients, however, we accounted for this potential source

of bias by adjusting for race in our models.[44] Therefore, it is possible that poverty itself, independent of race, represents a driver of biased referrals.

A second potential mechanism for lower pulmonary utilization in areas with higher neighborhood disadvantage is unmet increased demand for pulmonary specialty care following referral. Our prior research demonstrates increased COPD prevalence in neighborhoods with higher disadvantage,[6] potentially reflecting higher competition for limited pulmonologist supply.[45] Drive distance or time, frequently used proxies for physical access to health care, consistently overestimate access to healthcare services in urban compared to rural areas, as these proxies fail to account for higher demand in urban regions.[46] This may help explain our observation that nearly all the reductions in pulmonary utilization, total outpatient costs, and encounter costs seen for patients from more disadvantaged neighborhoods were driven by differences among urban veterans.

Lastly, patients in areas of higher neighborhood disadvantage may perceive lower acceptability and lower need for services.[12] The healthcare system has been designed to harm, oppress, and marginalize certain individuals, groups, and communities.[47] Internalized trauma and discrimination may impact care seeking behavior.[48] Additionally, social capital, which refers to the networks of relationships that facilitate cooperation and mutual support, varies across neighborhoods.[49] Reduced social capital in more disadvantaged neighborhoods may impact health-related behaviors.[50]

While the differences in pulmonary utilization and costs were statistically significant, their clinical significance warrants consideration. At the individual patient level, a reduction in pulmonary visits of 0.15 per year for those residing in the most disadvantaged neighborhoods may not be clinically meaningful. However, at the health systems level, especially for a value-based system such as the VA, this represents about 17,000 fewer pulmonary visits for our cohort from the most

disadvantaged neighborhoods. For a vulnerable population, these are missed opportunities to improve the quality of care.[41] Similarly, a reduction of $191.87 in total outpatient costs incurred by patients from the most disadvantaged neighborhoods compared to the least may not be felt at the individual level, however, this represents almost twenty-two million fewer dollars spent for our cohort of patients from the most disadvantaged neighborhoods. This may indicate meaningful disparities in health service intensity at the population level.

Our results support a population approach that harmonizes COPD care by proactively identifying and addressing patient needs. A systematic approach, such as collaborative care models, may be less reliant on traditional referral mechanisms that risk some patients and populations being underserved by the healthcare system.[51–53] Such population based systems of care naturally align with value-based repayment models which themselves promote health equity as a core tenant.[54–56] Though a shift towards proactive, collaborative population management may require upfront costs, the economic burden of COPD increases with higher disease severity and exacerbation frequency, so upfront investment are likely to be offset by downstream cost savings.[57]

This study had several strengths. We captured individual-level data across a large national population. By using data from the VA, a national, integrated, single-payer health care system, we were able to examine outpatient utilization and cost independent of insurance status. However, our study also has potential weaknesses. First, our results may be less generalizable to patients without health insurance, as insurance status and healthcare utilization are strongly associated.[58] Second, our COPD definition required two outpatient COPD diagnosis codes, which may fail to capture patients from neighborhoods with access barriers. However, this would bias our results towards the null hypothesis, and the true association between neighborhood disadvantage and utilization and costs may be even greater than what we observed in our data. Third, our data did not include Medicare or commercial insurance claims data and therefore may miss non-VA utilization

and costs. We addressed this limitation by excluding veterans who were not enrolled in VA-based primary care, as these patients may have less incentive to exclusively utilize VA services. Fourth, we did not standardize cost data to account for area- and policy-based payment differentials that could account for some of the observed geographic variability in costs.[59] It is possible that less disadvantaged neighborhoods may be concentrated in areas with higher healthcare costs, thereby explaining some of our observed differences in outpatient costs. We partially addressed geographic healthcare cost differentials by adjusting our models for clustering at the facility level. Lastly, we used the 2018 Area Deprivation Index, which does not temporally precede the outcome for all patients in our cohort, specifically those enrolled between 2010 and 2014. However, prior studies have shown that neighborhood poverty is fairly rigid over time.[60]

CONCLUSIONS

This study suggests that increased neighborhood disadvantage is associated with decreased subsequent outpatient pulmonary utilization and decreased visit-related costs, particularly for urban patients, potentially contributing to worse COPD outcomes. These results suggest that patients from vulnerable communities may be underserved by the healthcare system and may explain the observed association between increasing neighborhood disadvantage and worse COPD outcomes. The results of this study justify health system interventions to understand and mitigate access barriers for patients from socioeconomically disadvantaged communities.

Table 1. Baseline cohort characteristics by lowest and highest ADI quartile

Characteristic	Overall (n=455,373)	Lowest ADI Quartile (n=110,020)	Highest ADI Quartile (n=113,870)	Standardized Mean Difference
Age at index, mean (SD), yr	66 (12)	66 (13)	65 (12)	0.12
Sex, F, n (%)	16,336 (4%)	3,754 (3%)	4,223 (4%)	-0.02
Race, n (%)				0.20
Black/African American	48,788 (11%)	10,223 (9%)	18,218 (16%)	
American Indian/Alaska Native	2,910 (0.6%)	654 (0.6%)	859 (0.8%)	
Native Hawaiian/Pacific Islander	2,562 (0.6%)	796 (0.7%)	564 (0.5%)	
Asian	1,045 (0.2%)	1,112 (1%)	82 (0%)	
Multiracial	3,175 (0.7%)	822 (0.8%)	768 (0.7%)	
White	371,656 (812%)	89,825 (82%)	87,747 (77%)	
VA service-connectedness, mean (SD)	56 (35)	58 (35)	55 (35)	0.10
VA Priority Group, n (%)				0.31
Priority Group 1	129,933 (29%)	33,477 (30%)	30,069 (26%)	
Priority Group 2	25,945 (6%)	6,141 (6%)	6,488 (6%)	
Priority Group 3	44,066 (10%)	10,685 (10%)	10,668 (9%)	
Priority Group 4	22,898 (5%)	5,310 (5%)	6,650 (6%)	
Priority Group 5	147,736 (32%)	30,173 (27%)	43,579 (38%)	
Priority Group 6	12,337 (3%)	3,488 (3%)	2,228 (2%)	
Priority Group 7	11,951 (3%)	4,862 (4%)	1,442 (1%)	
Priority Group 8	60,012 (13%)	15,769 (14%)	12,641 (11%)	
Drive distance to VA, mean (SD), mi	31.92 (71.20)	27.11 (73.26)	35.04 (71.57)	-0.23
Urban/rural status, n (%)				0.56
Urban	250,064 (55%)	80,969 (74%)	52,586 (46%)	
Rural	196,198 (43%)	27,934 (25%)	58,101 (51%)	
Highly Rural	8,204 (2%)	890 (1%)	2,978 (3%)	
Isolated	6 (0%)	3 (0%)	1 (0%)	
Body mass index, n (%)				0.08
Underweight	12,852 (3%)	2,780 (3%)	3,832 (3%)	
Normal	109,937 (25%)	26,650 (25%)	28,877 (26%)	
Overweight	136,883 (31%)	34,842 (33%)	32,814 (30%)	
Obese	179,655 (41%)	42,265 (40%)	44,266 (40%)	
Current smoker, n (%)	203,957 (45%)	41,372 (38%)	58,377 (51%)	-0.09
Charlson comorbidity index, mean (SD)	4 (3)	4 (3)	4 (3)	-0.03
Baseline outpatient utilization (encounters), mean (SD)	4.69 (6.57)	4.95 (6.93)	4.67 (6.36)	0.04
Baseline outpatient costs (2018 dollars), mean (SD)	2,781.60 (3266.70)	3,016.01 (3783.80)	2,718.56 (2,963.40)	0.09
Number of distinct medications prescribed, mean (SD)	3.30 (2.06)	3.23 (2.02)	3.38 (2.09)	-0.08

Table 2. Association of Neighborhood Disadvantage with Utilization and Costs

Outcome	Lowest ADI Quartile (n=110,020)	Highest ADI Quartile (n=113,870)	Average Marginal Effects (95% CI)*	
			Unadjusted	Adjusted+
1-yr outpatient utilization (encounters), mean (SD)	3.03 (4.15)	2.83 (3.88)	-0.19 (-0.37, -0.01)	-0.12 (-0.29, 0.05)
Primary care	0.57 (1.27)	0.58 (1.27)	0.02 (-0.06, 0.10)	-0.02 (-0.10, 0.05)
Pulmonary	0.84 (1.70)	0.68 (1.37)	-0.17 (-0.24, -0.10)	-0.14 (-0.21, -0.07)
Cardiology	0.61 (1.85)	0.5 (1.94)	-0.02 (-0.07, 0.03)	0.02 (-0.04, 0.09)
Emergency Department	0.88 (2.15)	0.84 (2.03)	-0.04 (-0.14, 0.06)	-0.002 (-0.11, 0.10)
Urgent care	0.13 (0.70)	0.15 (0.83)	0.02 (-0.04, 0.09)	0.01 (-0.06, 0.08)
1-yr outpatient costs, mean (SD), 2018 dollars	2,667.52 (3,226.50)	2,431.28 (2,747.07)	-236.10 (-368.15, -104.05)	-192.49 (-314.29, -70.70)
Outpatient encounter costs	1,518.35 (2,442.26)	1,298.30 (2,084.41)	-220.01 (-338.36, -101.66)	-175.83 (-278.14, -73.52)
Medication costs	1,080.00 (1,736.38)	1,072.16 (1,471.05)	-7.84 (-39.43, 23.75)	-14.03 (-56.79, 28.74)

*Average marginal effects are the changes in utilization and cost outcomes (number of encounters and 2018 dollars, respectively) associated with exposure to residence in neighborhoods with the highest quartile of disadvantage after adjustment for confounders.

+Adjusted for age, sex, race, ethnicity, VA service-connectedness, VA priority group, drive distance to primary care, rurality, body mass index, smoking status, Charlson comorbidity index.

Table 3. Association of Neighborhood Disadvantage with Clinical Outcomes

Outcome	Lowest ADI Quartile (n=110,020)	Highest ADI Quartile (n=113,870)	Odds Ratio (95% CI)	
			Unadjusted	Adjusted+
Death, n (%)	9,203 (8%)	9,554 (8%)	1.00 (0.96, 1.04)	1.07 (1.00, 1.13)
COPD exacerbation♦ or death, n (%)	25,476 (23%)	28,484 (25%)	1.11 (1.05, 1.17)	1.13 (1.06, 1.20)
Hospitalization for COPD exacerbation or death, n (%)	11,851 (11%)	12,658 (11%)	1.04 (0.99, 1.09)	1.09 (1.02, 1.16)

+Adjusted for age, sex, race, ethnicity, VA service-connectedness, VA priority group, drive distance to primary care, rurality, body mass index, smoking status, Charlson comorbidity index.

♦Outpatient or inpatient COPD exacerbation.

Table 4. Association of Neighborhood Disadvantage with Utilization and Cost by Urban and Rural Status

Outcome	Urban Residence			Rural Residence			Interaction P-value[#]
	Lowest ADI Quartile (n=61,758)	Highest ADI Quartile (n=63,729)	Average Marginal Effects (95% CI)[*+]	Lowest ADI Quartile (n=48,887)	Highest ADI Quartile (n=53,226)	Average Marginal Effects (95% CI)[*+]	
1-yr outpatient utilization (encounters), mean (SD)	3.29 (4.42)	3.14 (4.38)	-0.30 (-0.57, -0.02)	2.53 (3.49)	2.55 (3.34)	-0.02 (-0.14, 0.10)	0.15
Primary care	0.57 (1.30)	0.54 (1.25)	-0.06 (-0.17, 0.05)	0.61 (1.35)	0.62 (1.29)	-0.01 (-0.09, 0.07)	0.28
Pulmonary	0.93 (1.80)	0.73 (1.44)	-0.24 (-0.35, -0.14)	0.68 (1.47)	0.63 (1.30)	-0.05 (-0.11, 0.01)	0.003
Cardiology	0.66 (1.96)	0.67 (2.32)	0.02 (-0.08, 0.12)	0.51 (1.58)	0.51 (1.45)	0.002 (-0.05, 0.06)	0.67
Emergency Department	0.99 (2.35)	1.08 (2.41)	0.01 (-0.14, 0.16)	0.60 (1.59)	0.61 (1.58)	-0.01 (-0.12, 0.10)	0.46
Urgent care	0.13 (0.71)	0.12 (0.75)	-0.02 (-0.09, 0.05)	0.13 (0.70)	0.18 (0.89)	0.05 (-0.05, 0.15)	0.27
1-yr outpatient costs, mean (SD), 2018 dollars	2,844.62 (3,354.37)	2,603.94 (3,068.68)	-321.01 (-527.63, -114.39)	2,314.01 (2,540.24)	2,269.50 (2,403.99)	-67.41 (-146.08, 11.27)	0.22
Outpatient encounter costs	1,701.55 (2,686.82)	1,466.14 (2,403.24)	-326.07 (-510.13, -142.00)	1,173.26 (1,845.07)	1,147.71 (1,772.34)	-42.06 (-104.81, 20.68)	0.04
Medication costs	1,074.00 (1,565.17)	1,077.13 (1,550.56)	0.75 (-55.00, 56.50)	1,077.81 (1,507.02)	1,060.10 (1,339.31)	-32.89 (-73.73, 7.95)	0.07

[*]Average marginal effects are the changes in utilization and cost outcomes (number of encounters and 2018 dollars, respectively) associated with exposure to residence in neighborhoods with the highest quartile of disadvantage after adjustment for confounders.

[+]Adjusted for age, sex, race, ethnicity, VA service-connectedness, VA priority group, drive distance to primary care, body mass index, smoking status, Charlson comorbidity index.

[#]Statistical significance defined as P<0.10 for interactions

Table 5. Association of Neighborhood Disadvantage with Clinical Outcomes by Urban and Rural Status

Outcome	Urban Residence			Rural Residence			Interaction P-value[#]
	Lowest ADI Quartile (n=61,758)	Highest ADI Quartile (n=63,729)	Odds Ratio (95% CI)[+]	Lowest ADI Quartile (n=48,887)	Highest ADI Quartile (n=53,226)	Odds Ratio (95% CI)[+]	
Death, n (%)	5,262 (9%)	5,384 (8%)	1.07 (0.98, 1.16)	3,901 (8%)	4,421 (8%)	1.06 (0.98, 1.13)	0.74
COPD exacerbation[♦] or death, n (%)	14,521 (24%)	16,554 (26%)	1.15 (1.07, 1.24)	10,874 (22%)	12,838 (24%)	1.09 (1.02, 1.18)	0.32
Hospitalization for COPD exacerbation or death, n (%)	6,902 (11%)	7,432 (12%)	1.10 (1.01, 1.20)	4,831 (10%)	5,665 (11%)	1.08 (1.00, 1.16)	0.87

[+]Adjusted for age, sex, race, VA service-connectedness, VA priority group, drive distance to primary care, body mass index, smoking status, Charlson comorbidity index.

[♦]Outpatient or inpatient COPD exacerbation.

[#]Statistical significance defined as P<0.10 for interactions

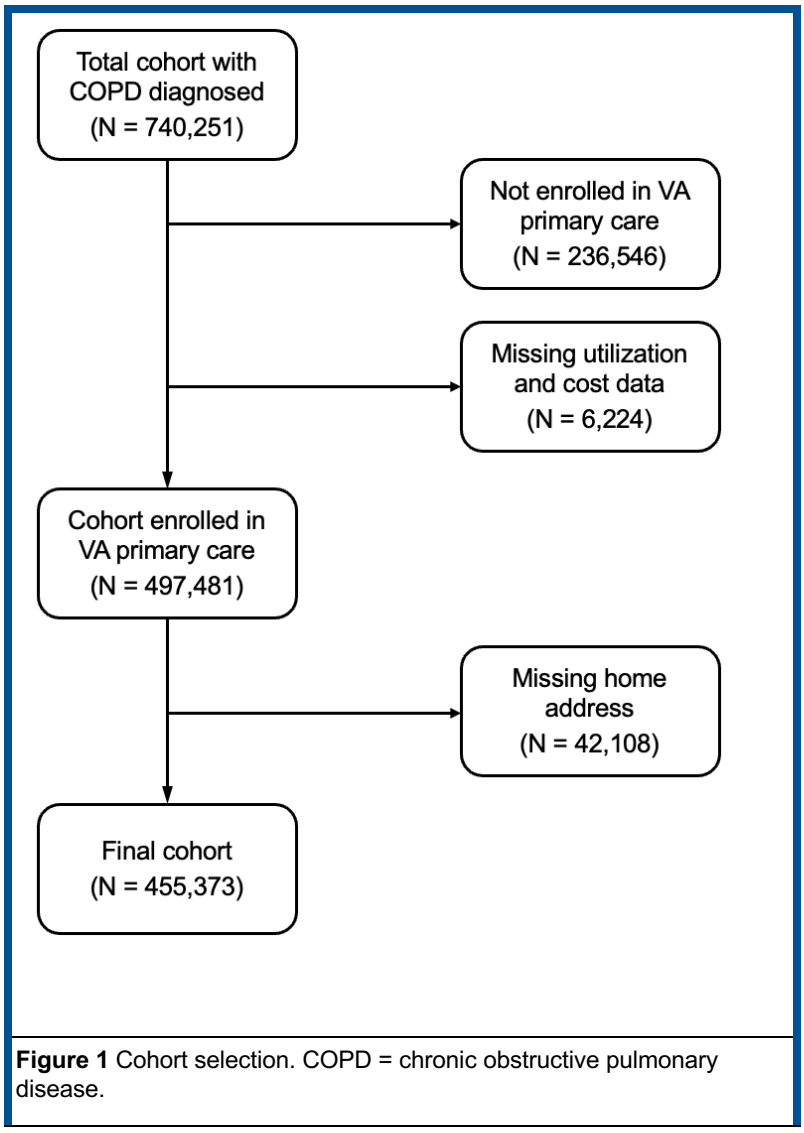

Figure 1 Cohort selection. COPD = chronic obstructive pulmonary disease.

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