Original Research

Disparities in Hospitalized Chronic Obstructive Pulmonary Disease Exacerbations Among American Indians and Non-Hispanic Whites

Huimin Wu, MD, MPH1 Dorothy A. Rhoades, MD, MPH2 Sixia Chen, PhD3 Matt Slief, MD4 Carla A. Guy, BS3 Adam Warren, BS3 Brent Brown, MD1

1. Pulmonary, Critical Care and Sleep Medicine Section, College of Medicine, University of Oklahoma Health Sciences Center, Oklahoma City, Oklahoma, United States
2. General Internal Medicine, College of Medicine, and Stephenson Cancer Center, University of Oklahoma Health Sciences Center, Oklahoma City, Oklahoma, United States
3. Biostatistics and Epidemiology, College of Public Health, University of Oklahoma Health Sciences Center, Oklahoma City, Oklahoma, United States
4. College of Medicine, University of Oklahoma Health Sciences Center, Oklahoma City, Oklahoma, United States

Corresponding author:
Huimin Wu, MD, MPH
Phone: 405-271-6173
Email: Huimin-Wu@ouhsc.edu

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List of the abbreviations
ADI = Area Deprivation Index
AI = American Indian
BMI = Body mass index
CI = Confidence interval
COPD = Chronic obstructive pulmonary disease
CT = Computed tomography
DM = Diabetes mellitus
EHR = Electronic health record
ICD = International Classification of Diseases
ICU = Intensive care unit
IQR = Interquartile range
LOS = Length of stay
NHW = Non-Hispanic White
OR = Odds Ratio
OUMC = University of Oklahoma Medical Center
SD = Standard deviation

List of keywords
American Indian, Chronic obstructive pulmonary disease, Health disparities, Non-Hispanic White

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Abstract

Background

The prevalence of chronic obstructive pulmonary disease (COPD) is high in American Indian (AI) populations, as are diabetes and obesity, which are common COPD comorbidities. However, COPD research among AI populations is limited.

Study Design and Methods

We conducted a retrospective study to investigate potential health disparities and risk factors among AI and non-Hispanic White (NHW) patients with COPD exacerbations hospitalized at the University of Oklahoma Medical Center between July 2001 and June 2020. Demographics, clinical variables and outcomes were collected.

Results

A total of 76 AI patients and 304 NHW patients were included. AI patients had more comorbidities than did NHW patients (4.3 vs. 3.1, p<0.001). In multiple variable analyses, AI race was associated with higher odds of needing intensive care unit (ICU) care (Odds Ratio [OR], 2.37, 95% Confidence interval [CI], 1.36-4.16, p=0.002) and invasive mechanical ventilator use (OR, 2.75, 95% CI, 1.42-5.29, p=0.002). AI race was also associated with longer ICU stay compared with NHW (OR, 1.43, 95% CI, 1.18-1.73, p<0.001). The average number of days on mechanical ventilator support would increase by 137.3% for an AI patient compared to a NHW patient (p<0.001). AI race was not associated with discharge to other health facilities (OR, 0.98, 95% CI, 0.52-1.83, p=0.944).

Interpretation
AI patients were more likely than NHW patients to need ICU care and ventilator support, have longer ICU stays, and days on mechanical ventilator support. More studies are needed to identify reasons for these disparities and effective interventions to reduce them.
Text

Introduction

Chronic obstructive pulmonary disease (COPD) is a major cause of chronic morbidity and one of the top three causes of death worldwide.\textsuperscript{1} Cigarette smoking is the most common risk factor for COPD, and type 2 diabetes mellitus (DM) and obesity are common comorbidities.\textsuperscript{1} COPD has only rarely been studied among American Indian (AI) populations, despite their having the highest prevalence of smoking\textsuperscript{2-5}, diabetes\textsuperscript{6,7} and obesity.\textsuperscript{8,9} Many AI communities are in medically underserved areas,\textsuperscript{10} with reduced access to specialty care. AIs are therefore likely to have a high risk of poor COPD outcomes. Although COPD health disparities in the United States have been reported for non-Hispanic white (NHW) and African American patients,\textsuperscript{11-15} no published research on COPD health disparities has included AI persons.

COPD research of any kind among AI populations is also scarce. The most recent report of COPD prevalence among AIs in the U.S. was in 2011, when the prevalence (11\%) was higher among AIs than among any other racial group in the U.S.\textsuperscript{16} We recently provided one of the few descriptive studies of COPD exacerbations among AI persons who had emergency department visits or were hospitalized with COPD,\textsuperscript{17} finding high prevalence of comorbidity and need for intensive care.

Oklahoma has the highest percentage by population of AIs affiliated with federally recognized tribes in the country.\textsuperscript{18} Furthermore, Oklahoma has a very high COPD prevalence and mortality.\textsuperscript{19} We conducted a single-center retrospective pilot study to investigate COPD health disparities between AIs and NHWs at the University of Oklahoma Medical Center (OUMC).

Methods
Study Population and Setting

The University of Oklahoma Health Sciences Center Institutional Review Board approved this study (number: 10716). A waiver of informed consent was granted due to the retrospective chart review nature of the study.

OUMC is the largest academic medical center and major transfer center in Oklahoma, and has the state’s largest intensive care unit (ICU). The study population included AI and NHW men and women ages 18 and older who were hospitalized for COPD exacerbations between July 2001 and June 2020 at OUMC. Patients were included if they were discharged from the medical center or died during the hospitalization with a diagnosis of COPD, defined by International Classification of Diseases (ICD) codes (ICD-9: 490, 491, 494, 496, ICD-10: J41-44), and were treated for COPD-related acute events, such as worsening shortness of breath and acute respiratory failure. Encounters for patients who had stable COPD but were admitted for management of another condition or for other chronic respiratory disease management, such as interstitial lung disease, bronchiectasis, and lung transplantation, were excluded.

Patients were also included if they self-identified as AI or NHW during the hospital intake process, as noted in the electronic health record (EHR). AI patients were matched initially 1:20 with NHW patients in the same month of first COPD hospitalization. During data collection, the power was recalculated, as investigators noticed that higher numbers of matching chart reviews did not increase the study power. AI patients were matched 1:4 with NHW patients for final data analysis.

Data Collection
The data collected from the EHR included race, age at last encounter, gender, smoking history as defined at the last visit (current, former, never, unknown), home address, insurance information, date of visit, height, weight, admission locations, comorbidities (described below), use of supplemental oxygen on discharge, history of prior OUMC hospitalization for COPD exacerbation during the study time frame, and any recorded pulmonary function test and ever recorded chest computed tomography (CT) result during the study time frame. The COPD health outcome variables include hospital length of stay (LOS, from the day of admission to the day of discharge or death), ICU days, invasive mechanical ventilator use, supplemental O2 use on discharge, discharge disposition (home with self-care, home with home health, rehabilitation facility, long-term acute care, skilled nursing, and others), 30-day readmission, and death.

Comorbidities included cardiovascular diseases (coronary artery disease, heart failure, hypertension, peripheral vascular disease, arrhythmias, and stroke), metabolic diseases (DM and dyslipidemia), pulmonary and sleep disorders (asthma, lung cancer, and obstructive sleep apnea), and others (obesity, osteoporosis, anxiety/depression, gastroesophageal reflux, chronic kidney disease, and anemia). Comorbidity index is the total number of the above comorbid diseases.

Obesity was defined by standard categories of the body mass index (BMI; weight in kilograms divided by the square of the height in meters). BMI was classified into six categories: underweight (BMI < 18.5), normal (BMI 18.5–24.99), overweight (BMI 25.0–29.99), obesity class I (BMI 30.0–34.99), obesity class II (BMI 35.0–39.99), and obesity class III (BMI of 40.0 or higher).

Patients’ addresses were used to identify their respective U.S. Census block group. An Area Deprivation Index (ADI) system was used to rank patients’ neighborhood socioeconomic disadvantage according to the respective U.S. Census block group. The ADI includes factors...
of income, education, employment, and housing quality. The ADIs are provided in national percentile rankings at the block group level from 1 to 100. Group 1 is the lowest ADI (the lowest level of ‘disadvantage’) and group 100 is the highest ADI (the highest level of ‘disadvantage’).

The payment sources were classified as Medicare, Medicaid, commercial insurance, Indian health coverage (including Indian Health Service or Tribal health program), other insurance, and uninsured. A patient may have more than one payment source.

Trained research staff reviewed every chart manually to confirm eligibility for inclusion, treatment for COPD exacerbation, smoking history, and comorbidities. The project principal investigator, a board-certified practicing pulmonologist, reviewed more than 20% of the charts abstracted by research staff to ensure quality control.

**Analysis plan**

Continuous variables are expressed as mean ± SD, or median (interquartile range [IQR]), while categorical variables are shown as percentages. For between group comparisons, if the normality assumption held, we used independent *t*-test; if normality assumption was not correct, we used nonparametric tests, including the Wilcoxon rank sum test (for 2 groups). Chi-square test was used to evaluate the relationship between two categorical variables if we did not have sparse cells. Fisher’s exact test was used for sparse cells. A two-tailed *p* value <0.05 was considered statistically significant.

Linear regression model analysis was performed to determine the association between continuous health outcome variables (hospital LOS, ICU days and mechanical ventilator support days) and predictors (e.g., race, age, gender, smoking history, ADI, DM, obesity, number of comorbidities, number of COPD rehospitalizations). Log transformations were performed for
non-normally distributed variables: hospital LOS, ICU days, and ventilator support days. Logistic regression model analysis was performed to determine the association between categorical health outcome variables (admission locations, history of mechanical ventilator use, supplemental O₂ use, discharge disposition and 30-days readmission), and predictors. Exact logistic regression was used for low numbers of cases.

Single variable analysis (α level = 0.05) and collinearity were used in both linear and logistic models. For linear models, assumptions including independence, normality, and equal variance were examined by using residual plots and qq plots.

Data analysis was performed using SAS software version 9.4 and R, R Core Team (2017) (R Foundation for Statistical Computing, URL https://www.R-project.org/). Before analysis was conducted missing values were removed.

Results

A total of 630 encounters with the diagnosis of COPD in AI patients were initially identified in the OUMC EHR. After excluding emergency department visits, ambulatory encounters, and no confirmed treatment for COPD exacerbation, 76 AI patients with 128 encounters met the inclusion criteria (Figure 1). The index COPD hospitalization of each of these 76 AI patients was matched 1:4 to 304 NHW patients (448 encounters) by the same month of the admission.

Table 1 shows single variable comparisons between AI and NHW patients. Although not statistically significant, we found that AI patients were on average three years younger than NHW patients. A higher proportion of females were present in the AI group (61%) than in the NHW group (48%). In both groups, most patients were current or ex-smokers. Most participants in both groups lived in urban areas and areas above the national median of ADI national rank.
Although the difference was not statistically significant, the proportion of AI patients living in the least disadvantaged areas was lower than the proportion of NHW patients living in the least disadvantage areas. Most patients had an identified health care payment source. The proportion of patients without health care coverage did not differ by race. AI patients had more comorbid diseases than did NHW patients. The prevalence of DM among AI patients was nearly twice that among NHW patients. Lung cancer, peripheral vascular disease, and anemia were nearly three times as prevalent among AI patients. Although the difference was not statistically significant, more AI patients were overweight or obese than were NHW patients (69.7% vs. 58.5%, respectively). The prevalence of class III obesity among AI patients was more than twice that among NHW patients.

Table 2 shows single variable hospital care and outcomes by AI and NHW race. Initial admission locations, hospital LOS, and discharge disposition (including death) did not differ by race. However, the percentage of AI patients ultimately needing ICU care and invasive mechanical support was significantly higher than that for NHW patients. Similarly, the number of days of ICU and invasive mechanical ventilator support was greater for AI patients than for NHW patients. On the other hand, the proportion of AI patients discharged with supplemental oxygen was lower than that in NHW patients. Although the percentage of COPD readmission in 30 days was comparable and low in both groups, AI patients more often had a history of prior COPD hospitalization, prior ICU stay, and prior invasive mechanical ventilator support.

Analyses assessing whether AI race was independently associated with hospital outcomes are presented in Tables 3-7. Although not statistically significant, the odds of requiring admission to the ICU for AI patients were twice as great as that for NHW patients after adjustment for other significant cofactors (Table 3). Admission to stepdown did not differ by race. Being male was
both significantly associated with ICU and stepdown admission. In the linear regression model with LOS as the outcome, each unit increase in the ADI national rank resulted in a 0.59\% decrease in average of LOS (Table 4).

AI patients’ odds of needing ICU and mechanical ventilator support during the study time frame were two or more times as large as those for NHW patients (Table 5). AI race was independently associated with longer ICU stay (Table 6). When on mechanical ventilator support, our records indicated the median duration of ventilator support was 4 days for AI patients and 2.5 days for NHW patients. The association between AI race and days requiring mechanical support was also significant in multiple variable analysis (Table 6). From the log transformed linear regression model, the average number of days on mechanical ventilator support would increase by 137.3\% for an AI patient compared to an NHW patient.

Although AI race was associated with a higher risk of all-cause mortality, the number of events was low and the association was not significant in exact logistic regression (Table 7). AI race was not significantly associated with discharge to other health facilities, such as long-term acute care, skilled nursing facilities, or rehabilitation facilities (OR 0.98, 95\% CI 0.52-1.83, \(p=0.94\)). However, AI patients with DM were more likely to be discharged to other health facilities than were AI patients without DM (OR 2.05, 95\% CI 1.22-3.51, \(p<0.01\)).

Only 18\% of AI patients and 27\% of NHW patients had pulmonary function data ever recorded in our health system (Table 8). While more than half the patients in both groups had ever received a chest CT, AI patients had chest CT images more often than did NHW patients.

Uninsured NHW patients had less supplemental O\(_2\) use (\(p<0.01\)) and were less likely to be discharged to other health facilities (\(p<0.01\)) than were insured NHW patients (supplemental
There was no difference by payment source in admission locations, ICU stay, ventilator use, or 30-day readmissions for insured vs. uninsured in both races.

**Discussion**

Increasing attention is being paid to differences in health outcomes in critical illness between racial and ethnic groups. Most available literature regarding COPD reflects differences between African Americans and NHWs. For example, a prior study revealed that African Americans with COPD exacerbations who were admitted to Veterans Affairs hospitals were more likely to be admitted to the ICU and to receive mechanical ventilation than were NHWs with COPD exacerbations. However, little data are available to investigate COPD among AI populations. Our study shows that AI race was associated with worse health outcomes, including more ICU admissions, longer ICU days, and longer invasive mechanical ventilator use, than was NHW race. Due to the limited sample size and retrospective chart review, we could not further characterize the underlying reasons for disparate outcomes.

In our study, hospitalized AI patients were slightly younger than NHW patients, although the difference did not reach statistical significance. Nonetheless, COPD pathology likely develops insidiously before the spirometric threshold for diagnosis is met. Identifying early COPD among AI populations is therefore critical to begin effective interventions.

COPD historically affected men with a history of smoking. Our study showed a higher proportion of women hospitalized for COPD in the AI group than in the NHW group. The high percentage of women in the AI group also exceeded that reported for women of other races hospitalized for COPD. This may reflect a higher proportion of smoking among AI women. Although being male was associated with higher risk of ICU and stepdown admission for both...
groups in our study, the high percentage of women in the AI group may be a unique feature that warrants additional study. Whether this demonstrates a greater willingness among AI women than men to seek care before becoming critically ill is unknown and merits further investigation.

Medical comorbidities are prevalent among patients with COPD. It is well known that COPD comorbidities may have a significant impact on disease course and prognosis. Most patients in our study had comorbidities. But AI patients had more comorbidities, especially DM, lung cancer, and peripheral vascular disease, than did NHW patients. They also had a non-significantly higher prevalence of class III obesity. A greater number of comorbid diseases may contribute to the poor COPD health outcome in AI patients, but our sample size may have limited our ability to detect meaningful associations. Early diagnosis and treatment of COPD comorbidities may be an important management strategy for AI patients with COPD.

Neighborhood disadvantage has been linked with health disparities in a large COPD cohort study in non-AI patients. COPD patients who resided in more-disadvantaged neighborhoods had worse COPD outcomes than did those residing in less-disadvantaged neighborhoods. While our study also showed this association, the average ADI National Rankings was 75.34 ± 19.58, much worse than patients in the afore mentioned study at 41.0± 29.4. However, ADI rankings did not differ significantly between AI and NHW groups in our study even though the proportion of least disadvantaged was lower for the AI group. Again, larger studies are needed to further explore the role of socioeconomic status. Strategies at the state level also have the potential to improve neighborhood socioeconomic status as a whole.

Although supplemental oxygen was prescribed less often to AI patients on discharge, AI patients had more use of ICU and invasive mechanical ventilation, as well as a history of repeated COPD hospitalizations. Our medical record review could not assess outpatient severity of COPD.
Reasons for these seemingly disparate findings are unclear. Potential explanations include lack of access to pulmonary specialty care or post-hospitalization primary care, shortage of medications, lack of COPD education in self-management, and patient preferences. Systematic studies are needed to characterize COPD within AI communities and to identify the risk factors for repeated hospitalizations.

Both AI and NHW patients had very low documentation of any spirometry testing in the system. Some patients may have spirometry in other health facilities. Others may not have spirometry due to transportation or no spirometry capability in the primary care providers’ office. The lack of spirometric data limits the accuracy of COPD diagnosis and disease progression monitoring. On the other hand, a high percentage of AI patients had had at least one chest CT result in the system. Although documenting the reason for obtaining the chest CT was beyond the scope of this study, chest CT may be another tool to diagnose COPD. 28

In assessing the limitations of our study, of first note is the small sample size from a single center. After applying exclusion criteria, the number of eligible cases was insufficient to reach the desired power to confidently identify factors associated with 30-day COPD readmission, the study’s initial primary outcome. Second, the medical center is a tertiary care facility and transfer center; some patients at this facility may have more advanced disease than do patients in community health facilities, limiting generalizability. Similarly, the majority of our AI patients resided in urban areas and may not reflect the experience of AI persons in rural areas, who may have fewer medical resources. (24) This also hampers our ability to generalize our results to AI populations statewide or nationwide. Third, as a retrospective medical record review, this study is subject to limitations including misdiagnosis and racial misclassification. For instance, the diagnosis of COPD exacerbation was based on physician documentation and coding, and may
not have been recorded in a uniform manner in the EHR. If encounters with COPD exacerbation were not coded correctly, these medical records would not be reviewed by research team. Similarly, race was determined by EHR demographic documentation, which is prone to misclassification of AI persons to another race,\textsuperscript{29} as are disease registries and clinical databases.\textsuperscript{30-32} Our study may not have identified all AI patients with COPD. Finally, the nature of the study precluded exploration of other effects that may be important among AI people, such as intergenerational or historical trauma and medical distrust.\textsuperscript{33, 34} Despite these limitations, data regarding COPD among AI people are lacking and this study is the first to attempt an in-depth exploration of COPD health disparities in this population. These findings may support efforts to design large, systematic studies to assess and address COPD in AI communities.

In conclusion, AI patients hospitalized with COPD exacerbations had unique characteristics and worse health outcomes than did NHW patients. This study provides preliminary data for future larger multicenter studies to address COPD health disparities in AI communities.
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HW, DAR, SC and BB conceptualized the study. HW and DAR produced the original manuscript. HW, MS and CG participated in the acquisition of the data and takes responsibility for the integrity of the data. SC, AW and HW performed data analysis. All coauthors critically assessed methodological and statistical approach, critically reviewed manuscript, and revised the manuscript. We thank Ms. Kathy Kyler for medical writing assistance.

Data Sharing statement:

Data sharing is not available.

Declaration of interest

The authors report no conflict of interest related to the publication of this paper.
References

1. Global strategy for the diagnosis, management, and prevention of chronic obstructive pulmonary disease. 2021 Report. 2021. https://goldcopd.org/2021-gold-reports/. Accessed June 27, 2021.

2. Substance Abuse and Mental Health Services Administration. Results from the 2013 National Survey on Drug Use and Health: summary of national findings. https://www.samhsa.gov/data/sites/default/files/NSDUHresultsPDFWHTML2013/Web/NSDUHresults2013.pdf. Accessed May 11, 2021.

3. Jamal A, Phillips E, Gentzke AS, et al. Current Cigarette Smoking Among Adults - United States, 2016. MMWR Morb Mortal Wkly Rep. 2018;67(2):53-59. doi:10.15585/mmwr.mm6702a1

4. Jamal A, King BA, Neff LJ, Whitmill J, Babb SD, Graffunder CM. Current Cigarette Smoking Among Adults - United States, 2005-2015. MMWR Morb Mortal Wkly Rep. 2016;65(44):1205-1211. doi:10.15585/mmwr.mm6544a2

5. Sakuma KK, Pierce JP, Fagan P, et al. Racial/Ethnic Disparities Across Indicators of Cigarette Smoking in the Era of Increased Tobacco Control, 1992-2019. Nicotine Tob Res. 2021;23(6):909-919. doi:10.1093/ntr/ntaa231

6. Jernigan VB, Duran B, Ahn D, Winkleby M. Changing patterns in health behaviors and risk factors related to cardiovascular disease among American Indians and Alaska Natives. Am J Public Health. 2010;100(4):677-83. doi:10.2105/ajph.2009.164285

7. Centers for Disease Control and Prevention. National Diabetes Statistics Report, 2014: Estimates of diabetes and its burden in the United States. 2014. https://stacks.cdc.gov/view/cdc/23442/cdc_23442_DS1.pdf. Accessed July 4th, 2021.
8. Subica AM, Agarwal N, Sullivan JG, Link BG. Obesity and Associated Health Disparities Among Understudied Multiracial, Pacific Islander, and American Indian Adults. *Obesity (Silver Spring)*. 2017;25(12):2128-2136. doi:10.1002/oby.21954

9. Cobb N, Espey D, King J. Health behaviors and risk factors among American Indians and Alaska Natives, 2000-2010. *Am J Public Health*. 2014;104 Suppl 3(Suppl 3):S481-9. doi:10.2105/ajph.2014.301879

10. Sarah Dewees BM. Twice Invisible: Understanding Rural Native America. 2017. https://www.usetinc.org/wp-content/uploads/bvenuti/WWS/2017/May%202017/May%2008/Twice%20Invisible%20-%20Research%20Note.pdf. Accessed July 1st, 2021.

11. Spitzer KA, Stefan MS, Priya A, et al. A Geographic Analysis of Racial Disparities in Use of Pulmonary Rehabilitation After Hospitalization for COPD Exacerbation. *Chest*. 2020;157(5):1130-1137. doi:10.1016/j.chest.2019.11.044

12. Ejike CO, Woo H, Galiatsatos P, et al. Contribution of Individual and Neighborhood Factors to Racial Disparities in Respiratory Outcomes. *Am J Respir Crit Care Med*. 2021;203(8):987-997. doi:10.1164/rccm.202002-0253OC

13. Mamary AJ, Stewart JJ, Kinney GL, et al. Race and Gender Disparities are Evident in COPD Underdiagnoses Across all Severities of Measured Airflow Obstruction. *Chronic Obstr Pulm Dis*. 2018;5(3):177-184. doi:10.15326/jcopdf.5.3.2017.0145

14. Shaya FT, Maneval MS, Gbarayor CM, et al. Burden of COPD, asthma, and concomitant COPD and asthma among adults: racial disparities in a medicaid population. *Chest*. 2009;136(2):405-411. doi:10.1378/chest.08-2304
15. Kirkpatrick d P, Dransfield MT. Racial and sex differences in chronic obstructive pulmonary disease susceptibility, diagnosis, and treatment. *Curr Opin Pulm Med*. 2009;15(2):100-4. doi:10.1097/MCP.0b013e3283232825

16. Ford ES, Croft JB, Mannino DM, Wheaton AG, Zhang X, Giles WH. COPD surveillance--United States, 1999-2011. *Chest*. 2013;144(1):284-305. doi:10.1378/chest.13-0809

17. Wu H, Rhoades DA, Chen S, Brown B. Native American Patients with Chronic Obstructive Pulmonary Disease Exacerbations in a Tertiary Academic Medical Center - A Pilot Study. *Int J Chron Obstruct Pulmon Dis*. 2021;16:1163-1170. doi:10.2147/copd.S299178

18. Centers for Disease Control and Prevention. Tribal population. 
https://www.cdc.gov/tribal/tribes-organizations-health/tribes/state-population.html. Updated December 21, 2018. Accessed June, 27, 2021.

19. Centers for Disease Control and Prevention. Chronic Disease Indicators. 
https://www.cdc.gov/cdi/. Accessed June, 27, 2021.

20. University of Wisconsin School of Medicine and Public Health, Department of Medicine. 
Neighborhood Atlas. https://www.neighborhoodatlas.medicine.wisc.edu/. Accessed May 12, 2021.

21. Soto GJ, Martin GS, Gong MN. Healthcare disparities in critical illness. *Crit Care Med*. 2013;41(12):2784-93. doi:10.1097/CCM.0b013e3182a84a43

22. Sarrazin MV, Cannon KT, Rosenthal GE, Kaldjian LC. Racial differences in mortality among veterans hospitalized for exacerbation of chronic obstructive pulmonary disease. *J Natl Med Assoc*. 2009;101(7):656-62. doi:10.1016/s0027-9684(15)30974-3

23. Agustí A, Hogg JC. Update on the Pathogenesis of Chronic Obstructive Pulmonary Disease. *N Engl J Med*. 2019;381(13):1248-1256. doi:10.1056/NEJMra1900475
24. Gonzalez AV, Suissa S, Ernst P. Gender differences in survival following hospitalisation for COPD. *Thorax*. 2011;66(1):38-42. doi:10.1136/thx.2010.141978

25. Stolz D, Kostikas K, Loefroth E, et al. Differences in COPD Exacerbation Risk Between Women and Men: Analysis From the UK Clinical Practice Research Datalink Data. *Chest*. 2019;156(4):674-684. doi:10.1016/j.chest.2019.04.107

26. Sin DD, Anthonisen NR, Soriano JB, Agusti AG. Mortality in COPD: Role of comorbidities. *Eur Respir J*. 2006;28(6):1245-57. doi:10.1183/09031936.00133805

27. Galiatsatos P, Woo H, Paulin LM, et al. The Association Between Neighborhood Socioeconomic Disadvantage and Chronic Obstructive Pulmonary Disease. *Int J Chron Obstruct Pulmon Dis*. 2020;15:981-993. doi:10.2147/copd.S238933

28. Labaki WW, Xia M, Murray S, et al. Quantitative Emphysema on Low-Dose CT Imaging of the Chest and Risk of Lung Cancer and Airflow Obstruction: An Analysis of the National Lung Screening Trial. *Chest*. 2021;159(5):1812-1820. doi:10.1016/j.chest.2020.12.004

29. Bigback KM, Hoopes M, Dankovchik J, et al. Using Record Linkage to Improve Race Data Quality for American Indians and Alaska Natives in Two Pacific Northwest State Hospital Discharge Databases. *Health Serv Res*. 2015;50 Suppl 1(Suppl 1):1390-402. doi:10.1111/1475-6773.12331

30. Jim MA, Arias E, Seneca DS, et al. Racial misclassification of American Indians and Alaska Natives by Indian Health Service Contract Health Service Delivery Area. *Am J Public Health*. 2014;104 Suppl 3(Suppl 3):S295-302. doi:10.2105/ajph.2014.301933

31. Hoopes MJ, Taulii M, Weiser TM, Brucker R, Becker TM. Including self-reported race to improve cancer surveillance data for American Indians and Alaska Natives in Washington state. *J Registry Manag*. 2010;37(2):43-8.
32. Grafova IB, Jarrin OF. Beyond Black and White: Mapping Misclassification of Medicare Beneficiaries Race and Ethnicity. *Med Care Res Rev*. 2020:1077558720935733. doi:10.1177/1077558720935733

33. Garcia AN, Castro MC, Sánchez JP. Social and Structural Determinants of Urban American Indian and Alaska Native Health: A Case Study in Los Angeles. *MedEdPORTAL*. 2019;15:10825. doi:10.15766/mep_2374-8265.10825

34. Nesoff ED, Brownstein JN, Veazie M, O'Leary M, Brody EA. Time-to-Treatment for Myocardial Infarction: Barriers and Facilitators Perceived by American Indians in Three Regions. *J Community Health*. 2017;42(1):129-138. doi:10.1007/s10900-016-0239-x
Figure titles and legends

**Figure 1.** Flow diagram for patient selection

**Figure 2.** American Indian and non-Hispanic White patients’ neighborhood locations and Area Deprivation Index national ranking distribution.
### Table 1. Basic characteristics of study population.

|                                | American Indians (n=76) | non-Hispanic Whites (n=304) | P Value |
|--------------------------------|-------------------------|-----------------------------|---------|
| Age, yr, mean (SD)             | 62.5 (9.7)              | 65.1 (10.6)                 | 0.055   |
| Sex, Female (%)                | 46 (60.6)               | 146 (48)                    | 0.051   |
| Smoking status, N (%)          |                         |                             |         |
| Current                        | 42 (55.3)               | 146 (48.2)                  | 0.463   |
| Ex-smoker                      | 31 (40.8)               | 133 (43.9)                  |         |
| Never smoker                   | 3 (4)                   | 19 (6.3)                    |         |
| Unknown                        | 0 (0)                   | 5 (1.7)                     |         |
| ADI National Rank, mean (SD)   | 77.7 (17.1)             | 74.7 (20.1)                 | 0.192   |
| ADI National Rank below national median (least disadvantaged), N (%) | 7 (9) | 51 (17) | 0.079 |
| BMI categories, N (%)          |                         |                             |         |
| Underweight                    | 5 (6.6)                 | 25 (8.2)                    | 0.167   |
| Normal weight                  | 18 (23.7)               | 98 (32.2)                   |         |
| Overweight                     | 19 (25)                 | 70 (23)                     |         |
| Class I obesity                | 12 (15.8)               | 43 (14.1)                   |         |
| Class II obesity               | 8 (10.5)                | 40 (13.2)                   |         |
| Class III obesity              | 14 (18.4)               | 25 (8.2)                    |         |
| Comorbidities, N (%)           |                         |                             |         |
| Coronary artery disease        | 25 (33)                 | 91 (30)                     | 0.616   |
| Heart Failure                  | 18 (24)                 | 64 (21)                     | 0.618   |
| Hypertension                   | 58 (76)                 | 205 (67)                    | 0.134   |
| Peripheral vascular disease    | 12 (16)                 | 6 (2)                       | < 0.001 |
| Arrhythmia                     | 12 (16)                 | 41 (13)                     | 0.604   |
| Stroke                         | 9 (12)                  | 22 (7)                      | 0.190   |
| Type 2 diabetes mellitus       | 36 (47)                 | 74 (24)                     | < 0.001 |
| Dyslipidemia                   | 18 (24)                 | 79 (26)                     | 0.681   |
| Asthma                         | 11 (14)                 | 30 (10)                     | 0.247   |
| Bronchiectasis                 | 0 (0)                   | 1 (0.4)                     | 0.999   |
| Pulmonary fibrosis             | 0 (0)                   | 1 (0.4)                     | 0.999   |
| Lung Cancer                    | 18 (24)                 | 23 (8)                      | < 0.001 |
| Obstructive sleep apnea        | 10 (13)                 | 34 (11)                     | 0.631   |
| Osteoporosis                   | 2 (3)                   | 0(0)                        | 0.005   |
| Anxiety/Depression             | 22 (29)                 | 89 (29)                     | 0.956   |
| Gastroesophageal reflux        | 17 (22)                 | 41 (13)                     | 0.054   |
| Chronic kidney disease         | 7 (9)                   | 30 (10)                     | 0.863   |
| Anemia                         | 14 (18)                 | 14 (5)                      | <0.001  |
| Comorbidity diseases, N mean (SD)| 4.3 (2.1)             | 3.1 (2.1)                   | <0.001  |
| Payment Source                  | N (%)    |       |
|--------------------------------|----------|-------|
| Medicare                       | 45 (59)  | 166 (55) |
| Medicaid                        | 21 (28)  | 95 (31)  |
| Indian Health Service           | 21 (28)  | 0     |
| Commercial                      | 12 (16)  | 27 (9)  |
| Other insurance                 | 2 (3)    | 72 (24) |
| Uninsured                       | 8 (11)   | 44 (14) |
| Number of hospitalization       | 128      | 448    |

Definition of abbreviations: ADI = Area Deprivation Index; BMI = Body mass index; SD = Standard deviation

a Due to missing data, 292 patients’ data were collected.
Table 2. Hospital care and health outcomes in American Indian and non-Hispanic White patients.

|                                | American Indians (n=76) | non-Hispanic Whites (n=304) | P Value |
|--------------------------------|-------------------------|-----------------------------|---------|
| Admission location, N (%)<sup>a</sup> |                         |                             |         |
| Medical floor                  | 36 (47)                 | 172 (57)                    | 0.114   |
| Stepdown unit                  | 14 (18)                 | 73 (24)                     |         |
| ICU                            | 22 (29)                 | 59 (19)                     |         |
| Hospital length of stay (days, mean [SD])<sup>a</sup> | 9.1 (15.1)             | 7.7 (11.0)                  | 0.816   |
| Discharge disposition, N (%)<sup>a</sup> |                         |                             |         |
| Home<sup>b</sup>               | 53 (70)                 | 214 (70)                    | 0.771   |
| Other<sup>c</sup>              | 18 (24)                 | 76 (25)                     |         |
| Expired                        | 5 (7)                   | 14 (5)                      |         |
| Need ICU care, N<sup>a</sup>    | 31 (40.8)               | 75 (24.7)                   | 0.005   |
| Days in ICU, day (IQR)<sup>a</sup> | 4 (2-8)                | 3 (2-7)                     | 0.211   |
| Need invasive mechanical ventilator support, N<sup>a</sup> | 19 (25.0)               | 36 (11.8)                   | 0.004   |
| Days on invasive mechanical ventilator support, day (IQR)<sup>d</sup> | 4 (2-6)                 | 2.5 (1.5-7)                 | 0.171   |
| Discharge with supplemental oxygen, N (%)<sup>a</sup> | 27 (35.5)               | 155 (51)                    | 0.014   |
| Have multiple COPD hospitalizations, N (%) | 26 (34)                | 63 (21)                     | 0.013   |
| Have COPD readmission in 30 days, N (%) | 4 (5)                  | 17 (6)                      | 0.911   |
| Ever had ICU stay, N (%)       | 37 (49)                 | 86 (29)                     | 0.001   |
| Ever need invasive mechanical ventilator support, N (%) | 23 (30)                 | 42 (14)                     | 0.001   |
| Ever been discharged with supplemental oxygen, N (%) | 32 (42)                 | 160 (53)                    | 0.090   |

Definition of abbreviations: ICU = Intensive care unit; IQR = interquartile range; SD = Standard deviation
<sup>a</sup> Last hospitalization
<sup>b</sup> Includes home with self-care and home with home health
<sup>c</sup> Includes long term acute care, skilled nursing facility, rehabilitation facility, and other health facilities
<sup>d</sup> for patients who was on invasive mechanical ventilator in the hospital only
Table 3. Logistic regression analyses for admission location variables (reference is medical floor).

| Variable                | Admitted to ICU | Admitted to Stepdown |
|-------------------------|-----------------|----------------------|
|                         | Odds Ratio      | 95% Odds Ratio CI    | P value | Odds Ratio | 95% Odds Ratio CI | P value |
| Intercept               | 0.05            | (0.01, 0.97)         | 0.047   | 0.15       | (0.01, 2.18)      | 0.164   |
| Race (American Indian)  | 1.91            | (0.99, 3.71)         | 0.055   | 0.84       | (0.41, 1.73)      | 0.636   |
| Age                     | 1.00            | (0.97, 1.03)         | 0.994   | 1.00       | (0.97, 1.03)      | 0.955   |
| Gender (Male)           | 1.79            | (1.03, 3.12)         | 0.039   | 2.02       | (1.19, 3.44)      | 0.009   |
| Current smoker          | 3.03            | (0.63, 14.54)        | 0.166   | 1.42       | (0.45, 4.44)      | 0.548   |
| Ex-smoker               | 2.56            | (0.54, 12.15)        | 0.238   | 1.14       | (0.37, 3.51)      | 0.823   |
| ADI National Rank       | 1.01            | (0.99, 1.02)         | 0.454   | 1.00       | (0.98, 1.04)      | 0.758   |
| Body mass index         | 1.01            | (0.98, 1.04)         | 0.462   | 1.01       | (0.98, 1.04)      | 0.558   |
| Comorbidity index       | 0.99            | (0.68, 1.44)         | 0.967   | 1.24       | (0.87, 1.77)      | 0.238   |
| Number of COPD hospitalizations | 0.93  | (0.73, 1.18)         | 0.540   | 1.09       | (0.92, 1.29)      | 0.307   |

Definition of abbreviations: ADI = Area Deprivation Index; CI = Confidence Interval; ICU = Intensive care unit

Table 4. Linear regression analyses for hospital length of stay (days) a.

| Variable                | Beta       | 95% CI log scale | Log Transformed | P value | Univariate Estimate b | Univariate P-value b |
|-------------------------|------------|------------------|----------------|---------|-----------------------|----------------------|
| Intercept               | 1.53       | (0.59, 2.46)     | 4.61           | 0.002   | -0.02                 | 0.87                 |
| Race (American Indian)  | 0.08       | (-0.16, 0.31)    | 1.08           | 0.523   | 0.004                 | 0.342                |
| Age                     | 0.01       | (-0.01, 0.01)    | 1.00           | 0.291   | 0.07                  | 0.483                |
| Gender (Male)           | 0.08       | (-0.11, 0.26)    | 1.08           | 0.415   | -0.08                 | 0.670                |
| Current smoker          | -0.07      | (-0.47, 0.34)    | 0.93           | 0.741   | -0.01                 | 0.948                |
| Ex-smoker               | -0.02      | (-0.42, 0.38)    | 0.98           | 0.918   | -0.01                 | 0.012                |
| ADI National Rank       | -0.01      | (-0.02, -0.01)   | 0.99           | 0.014   | 0.01                  | 0.374                |
| Body mass index         | 0.01       | (-0.01, -0.01)   | 1.01           | 0.098   | -0.01                 | 0.846                |
| Comorbidity index       | -0.07      | (-0.19, 0.06)    | 0.94           | 0.285   | 0.01                  | 0.666                |
| Number of COPD hospitalizations | 0.02 | (-0.05, 0.08)    | 1.02           | 0.588   | -0.02                 | 0.87                 |

Definition of abbreviations: ADI = Area Deprivation Index; CI = Confidence Interval

a Hospital length of stay has a log transformation.  b Analyses obtained through a univariate regression approach.
Table 5. Logistic regression analyses for the history of ICU stay and mechanical ventilator support.

| Variables                      | History of ICU stay                  | History of Ventilator support |
|--------------------------------|--------------------------------------|-------------------------------|
|                                | Odds Ratio | 95% Odds Ratio CI | P value | Univariate Estimate | Univariate P-value | Odds Ratio | 95% Odds Ratio CI | P value | Univariate Estimate | Univariate P-value |
| Intercept                      | 0.13       | (0.01 , 1.53)     | 0.111   | 2.41               | 0.001              | 0.02       | (0.01 , 0.46)     | 0.022   | 0.16               | <0.001              |
| Race (American Indian)         | 2.37       | (1.36 , 4.16)     | 0.002   | 0.99               | 0.534              | 2.75       | (1.42 , 5.29)     | 0.002   | 0.99               | 0.693               |
| Age                            | 1.00       | (0.97 , 1.02)     | 0.889   | 1.16               | 0.49               | 1.00       | (0.97 , 1.03)     | 0.886   | 0.85               | 0.557               |
| Gender (Male)                  | 1.30       | (0.81, 2.08)      | 0.280   | 3.51               | 0.049              | 0.97       | (0.53 , 1.78)     | 0.932   | 4.97               | 0.123               |
| Current smoker                 | 3.19       | (0.97 , 14.63)    | 0.084   | 2.69               | 0.123              | 4.55       | (0.84 , 85.11)    | 0.155   | 3.78               | 0.204               |
| Ex-smoker                      | 2.31       | (0.70 , 10.54)    | 0.212   | 1.00               | 0.935              | 3.26       | (0.60 , 60.97)    | 0.267   | 0.99               | 0.841               |
| ADI National Rank              | 1.00       | (0.99 , 1.01)     | 0.938   | 0.99               | 0.740              | 1.00       | (0.98 , 1.01)     | 0.750   | 1.02               | 0.195               |
| Body mass index                | 0.99       | (0.96 , 1.02)     | 0.453   | 1.34               | 0.032              | 1.01       | (0.98 , 1.05)     | 0.397   | 1.49               | 0.015               |
| Comorbidity index              | 1.23       | (0.90 , 1.69)     | 0.191   | 1.22               | 0.013              | 1.17       | (0.79 , 1.73)     | 0.421   | 1.24               | 0.008               |
| Number of COPD hospitalizations| 1.18       | (1.01 , 1.39)     | 0.045   | 2.41               | 0.001              | 1.21       | (1.02 , 1.44)     | 0.023   | 0.16               | <0.001               |

Definition of abbreviations: ADI = Area Deprivation Index; CI = Confidence Interval; ICU = Intensive care unit

*a Analyses obtained through a univariate regression approach.
### Table 6. Linear regression analyses for ICU days and days requiring mechanical ventilator support for the last hospitalization. a

| Variables                      | ICU days (Log) | Days requiring Mechanical Ventilator support (Log) |
|--------------------------------|----------------|-----------------------------------------------|
|                                | Beta  | 95% CI log scale | Transformed | P value | Univariate Estimate b | P value | Beta  | 95% CI log scale | Transformed | P value | Univariate Estimate b | P value |
| Intercept                      | 0.39  | (-0.39 , 1.18)   | 1.48       | 0.329   | 1.39 | 0.001 | 7.61  | (0.59 , 2.46)   | 2016.20 | <.001 | 0.24 | 0.001 |
| Race (American Indian)         | 0.36  | (0.16 , 0.55)    | 1.43       | <0.001 | -0.01 | 0.195 | 0.86  | (-0.16 , 0.31) | 2.37    | 0.003 | -0.01 | 0.065 |
| Age                            | -0.01 | (-0.01 , 0.01)   | 1.00       | 0.684   | 0.01 | 0.852 | -0.03 | (-0.01 , 0.01) | 0.97    | 0.012 | -0.04 | 0.467 |
| Gender (Male)                  | 0.03  | (-0.12 , 0.19)   | 1.03       | 0.668   | 0.33 | 0.049 | -0.36 | (-0.11 , 0.26) | 0.70    | 0.159 | 0.14 | 0.274 |
| Current smoker                 | 0.26  | (-0.08 , 0.60)   | 1.30       | 0.128   | 0.19 | 0.271 | -1.67 | (-0.47 , 0.34) | 0.19    | 0.036 | 0.01 | 0.917 |
| Ex-smoker                      | 0.16  | (-0.18 , 0.49)   | 1.17       | 0.360   | -0.002 | 0.227 | -1.53 | (-0.42 , 0.38) | 0.22    | 0.047 | -0.003 | 0.069 |
| ADI National Rank              | -0.01 | (-0.01 , 0.01)   | 1.00       | 0.122   | 0.001 | 0.875 | -0.02 | (-0.02 , -0.01) | 0.98    | 0.003 | 0.002 | 0.561 |
| Body mass index                | 6.00E-04  | (-0.01 , 0.01) | 1.00       | 0.902   | 0.03 | 0.477 | -0.01 | (-0.01 , 0.02) | 0.99   | 0.301 | -0.004 | 0.922 |
| Comorbidity index              | -0.01 | (-0.11 , 0.10)   | 1.00       | 0.946   | -0.02 | 0.524 | -0.48 | (-0.19 , 0.06) | 0.62    | 0.009 | -0.01 | 0.592 |
| Number of COPD hospitalization | -0.02 | (-0.07 , 0.04)   | 0.98       | 0.538   | 1.39 | 0.001 | -0.09 | (-0.05 , 0.08) | 0.92    | 0.196 | 0.24 | 0.001 |

Definition of abbreviations: ADI = Area Deprivation Index; CI = Confidence interval; ICU = Intensive care unit

a a log transformation was applied for the model. b Analyses obtained through a univariate regression approach.
Table 7. Exact logistic Regression of Mortality

| Race                  | Death | Survival | Odds Ratio | 95% CI     | P value |
|-----------------------|-------|----------|------------|------------|---------|
| Non-Hispanic Whites   | 14    | 290      | Ref.       |            |         |
| American Indian       | 5     | 71       | 1.46       | 0.40, 4.46 | 0.649   |

Definition of abbreviations: CI = Confidence Interval; Ref. = reference variable

Table 8. Pulmonary function test and chest CT image availability in the electronic health record.

|                                | American Indian (n=76) | Non-Hispanic Whites (n=304) |
|--------------------------------|------------------------|-----------------------------|
| Patients with available spirometry, N (%) | 14 (18.4)              | 82 (27.0)                   |
| FEV1, L, mean (SD)             | 1.66 (0.72)            | 1.53 (0.67)                 |
| FVC, L, mean (SD)             | 2.79 (1.22)            | 2.65 (0.94)                 |
| Patients with available chest CT, N (%) | 54 (71.1)              | 171 (56.3)                  |

Definition of abbreviations: CT = Computed tomography; FEV1 = forced expiratory volume in the first second; FVC = forced vital capacity; SD = Standard deviation
Figure 1:

Medical records identified in OUMC inpatient database using ICD-9: 490, 491, 494, 496, ICD-10: J41-44
Race = American Indian
Year = Jul, 2000 – Jun, 2020
Encounters = 630

Excluded:
- ED visit
- Non-ED Ambulatory encounters
- Not treated for COPD exacerbations
- Cannot confirm being treated for COPD exacerbations
Encounters = 502

American Indian patients who were admitted with COPD exacerbations
76 patients, 128 encounters

Match (All to NHW patients 1:20 by the same month of the index admission)

Medical records identified in OUMC inpatient database using ICD-9: 490, 491, 494, 496, ICD-10: J41-44
Race = Non-Hispanic White
Year = Jul, 2000 – Jun, 2020
Encounters = 2940
1119 encounters were reviewed

Excluded:
- ED visit
- Non-ED Ambulatory encounters
- Not treated for COPD exacerbations
- Cannot confirm being treated for COPD exacerbations
Encounters = 1671

Non-Hispanic White patients who were admitted with COPD exacerbations
304 patients, 448 encounters

Included in final data analysis
Figure 2:
Supplemental Table 1. Hospital and health outcomes in uninsured and insured patients.

|                                | American Indian (n =76) | Non-Hispanic White (n =304) |
|--------------------------------|-------------------------|-------------------------------|
|                                | Uninsured (n=8) | Insured (n =68) | P value | Uninsured (n=44) | Insured (n=260) | P value |
| Admission location, n (%)      |                        |                              |         |                        |                              |         |
| Medical floor                  | 4 (50)                 | 32 (50)                      | 0.26    | 28 (64)                 | 144 (55)                    | 0.17    |
| Stepdown                       | 0 (0)                  | 14 (22)                      | 12 (27) | 61 (24)                 |
| ICU                            | 4 (50)                 | 18 (28)                      | 0.73    | 4 (9)                   | 55 (21)                    |         |
| Hospital length of stay, (days, mean [SD]) | 7.88 (9.00)         | 9.21 (15.66)                 | 0.73    | 7.18 (9.75)             | 7.81 (11.23)                | 0.70    |
| Days in ICU, (days, mean [SD]) | 7.75 (11.59)          | 9.93 (21.76)                 | 0.77    | 7.80 (7.73)             | 4.49 (4.31)                | 0.40    |
| Mechanical ventilator support, (days, mean [SD]) | 6.75 (12.20)         | 7.12 (20.57)                 | 0.96    | 2.20 (3.50)             | 2.36 (4.33)                | 0.93    |
| Discharge disposition, n (%)   |                        |                              |         |                        |                              |         |
| Home                           | 6 (75)                 | 47 (69)                      | 0.43    | 41 (93)                 | 173 (67)                    | < 0.01  |
| Other                          | 1 (12.5)               | 17 (25)                      | 2 (5)   | 74 (28)                 |
| Expired                        | 1 (12.5)               | 4 (6)                        | 1 (2)   | 13 (5)                  |
| Need supplemental oxygen on discharge, n (%) | 4 (50)                 | 23 (34)                      | 0.44    | 12 (33)                 | 146 (54)                    | 0.01    |
| Have COPD readmission in 30 days, n (%)     | 1 (12.5)               | 3 (4)                        | 0.37    | 3 (7)                   | 14 (6)                      | 0.72    |

Definition of abbreviations: ICU = Intensive care unit; SD = Standard deviation