

Association Between Rural Residence and In-Hospital and 30-Day Mortality Among Veterans Hospitalized with COPD Exacerbations

This article was published in the following Dove Press journal:
International Journal of Chronic Obstructive Pulmonary Disease

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Background: We explored the relationship between rural residency and in-hospital mortality in patients hospitalized with COPD exacerbations.

Methods: We retrospectively analyzed COPD hospitalizations from 2011 to 2017 at 124 acute care Veterans Health Administration (VHA) hospitals in the US. Patient residence was classified using Rural Urban Commuting Area codes as urban, rural, or isolated rural. We stratified patient hospitalizations into quartiles by travel time from patient residence to the nearest VHA primary care provider clinic and hospital. Multivariate analyses utilized generalized estimating equations with a logit link accounting for repeated hospitalizations among patients and adjusting for patient- and hospital-level characteristics.

Results: Of 64,914 COPD hospitalizations analyzed, 43,549 (67.1%) were for urban, 18,673 (28.8%) for rural, and 2,692 (4.1%) for isolated rural veterans. In-hospital mortality was 4.9% in urban, 5.5% in rural, and 5.2% in isolated rural veterans ($P=0.008$). Thirty-day mortality was 8.3% in urban, 9.9% in rural, and 9.2% in isolated rural veterans ($P<0.001$). Travel time to a primary care provider and VHA hospital was not associated with in-hospital mortality among isolated rural and rural veterans. In the multivariable analysis, compared to urban veterans, isolated rural patients did not have increased mortality. Rural residence was not associated with in-hospital (OR=0.87; 95% CI=0.67–1.12, $P=0.28$) but was associated with increased 30-day mortality (OR=1.13; 95% CI=1.04–1.22, $P=0.002$). Transfer from another acute care hospital (OR=14.97; 95% CI=9.80–17.16, $P<0.001$) or an unknown/other facility (OR=33.05; 95% CI=22.66–48.21, $P<0.001$) were the strongest predictors of increased in-hospital mortality compared to patients coming from the outpatient sector. Transfer from another acute care facility was also a risk factor for 30-day mortality.

Conclusion: Potential gaps in post-discharge care of rural veterans may be responsible for the rural–urban disparities. Further research should investigate the exact mechanism that inter-hospital transfers affect mortality.

Keywords: pulmonary disease, chronic obstructive, epidemiology, mortality

Introduction

Chronic obstructive pulmonary disease (COPD) is a leading cause of mortality in the US¹ and worldwide² and is associated with high morbidity³ and resource utilization,^{3,4} including costs due to clinic visits, chronic therapy, and frequent hospitalizations. Patients with COPD experience exacerbations of the disease, defined as worsening of their respiratory symptoms, which occur more often as the disease progresses. Severe COPD exacerbations requiring admission to the hospital are associated with increased

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mortality,^{5–9} and are responsible for 70% of the direct healthcare costs of the disease.^{4,10}

The prevalence of COPD is approximately 8% and 5% in adults living in rural and urban areas, respectively, according to a Center of Disease Control (CDC) report.¹¹ In 2015, rural Medicare patients experience 27% more hospitalizations and 71% more deaths than urban patients.¹¹ Rural residence is also an independent risk factor for COPD exacerbations and this association persists after accounting for lung function and demographics.¹²

Rural residence is an independent risk factor for 30-day hospital mortality in patients hospitalized with COPD exacerbation after adjusting for patient- and hospital-level characteristics.¹³ Rural patients hospitalized with COPD exacerbations have higher 30-day mortality relative to urban patients¹³ which may result from suboptimal care prior to, during, or after hospitalization. Suboptimal care prior to COPD hospitalization or delay to receive appropriate care due to poor access may result in increased mortality among rural patients.¹⁴ It is unknown whether the rural residence is a risk factor for in-hospital mortality. We hypothesized that rural COPD patients have increased in-hospital mortality compared to urban patients. To investigate our hypothesis, we examined mortality of all COPD hospitalizations in the Veterans Health Administration (VHA) for rural and urban veterans. Moreover, we examined whether demographics, comorbidities, transfer from another hospital, hospital-level characteristics, and travel time to the nearest VHA primary care provider or hospital can explain the disparity in mortality between rural and urban patients.

Methods

This retrospective cohort study included all hospitalizations for a COPD exacerbation to 124 acute care VHA hospitals with a discharge date between October 1, 2011 (fiscal year 2011) to September 30, 2017 (fiscal year 2017). More than 9 million veterans are enrolled in the VHA, the largest health system in the US, with 1,255 inpatient and outpatient health care facilities.¹⁵ This work was approved by the Institutional Review Boards and Research and Development Committee at the Iowa City VA Health Care System [IRB 201712713]. The study was conducted in accordance with the Declaration of Helsinki. Patient informed consent was not required by Institutional Review Boards and Research and Development Committee at the Iowa City VA Health Care System

because the study examined only existing patient-level data. Patients' data were kept confidential.

Setting

We extracted data for hospitalizations between October 1, 2011 (fiscal year 2011) to September 30, 2017 (fiscal year 2017) from the Veterans Informatics and Computing Infrastructure (VINCI), an integrated system that includes VHA's electronic health records and administrative data retrospectively after October 2018. Admissions to VHA acute care hospitals were identified via the Corporate Data Warehouse using the inpatient domain. These datasets contain patient demographics including residential address and ZIP code, diagnosis, and procedure codes during admission, admission source, admission, and discharge dates.

Definitions

The study cohort was identified by the International Classification of Diseases, Ninth and Tenth Revisions, Clinical Modification (ICD-9-CM and ICD-10-CM) using 1) a principal diagnosis of COPD exacerbation (ICD-9-CM codes: 491.xx, 492.x, 429.0, or 496 or ICD-10-CM codes: J41, J43, J43.1, J43.2, J43.8, J43.9, J44.0, J44.1, J41.8, J42, or J44.9) or 2) a principal diagnosis of acute respiratory failure (ICD-9-CM: 518.81, 518.82, or 518.84; ICD-10-CM: J96.00, J96.01, J96.02, J96.11, J96.12, J96.20, J96.21, J96.22, J96.90, J96.92, or R06.03) with a secondary COPD diagnosis as previously done.¹⁶ Although the accuracy of ICD codes to diagnose COPD is above 70%, especially in the elderly individuals,^{17–19} we validated the accuracy using spirometric and radiographic data from our facility. We found that of 285 patients with a COPD diagnosis based on ICD codes, 226 (79.3%) had an FEV1/FVC<0.7 and/or an FEV1<80% with a residual volume or residual volume/total lung capacity ratio>120%, and another 29 (10.2%) had radiographic emphysema in the chest CT by the radiology report (total 89.5% of patients had objective findings of COPD).

Patient and facility rurality were defined using ZIP codes based on the Rural Urban Commuting Area (RUCA) codes. RUCA codes reflect measures of urbanization, commuting, and population density.^{13,20–23} RUCA codes were further condensed to designate an area as urban (RUCA codes: 1 and 1.1), rural (RUCA codes: 2, 2.1, 3, 4, 4.1, 5, 5.1, 6, 7, 7.1, 7.2, 8, 8.1, 8.2, and 9), and isolated rural (RUCA codes: 10, 10.2, 10.2, and 10.3)

categories as defined by the VHA Office of Rural Health.²⁴

A series of variables for each patient were created indicating: 1) risk-adjustment variables describing baseline patient characteristics, such as age, sex, Area Deprivation Index (ADI), race, and comorbidities; 2) travel time to a VHA primary care provider and VHA hospital; and 3) facility characteristics including COPD-case volume and facility complexity. ADI reflects socio-economic level of patient's residential location.^{25,26} Comorbidities were defined using ICD-9-CM and ICD-10-CM diagnosis codes within 1 year of admission in either the inpatient, outpatient, or fee basis data files, except pneumonia which was defined based on the presence of the corresponding diagnosis code during the hospitalization as previously.²⁷ In addition, obstructive sleep apnea was defined using ICD-9 diagnosis codes 327.2 or 780.57, or ICD-10 diagnosis codes G47.30–G47.39. We also obtained laboratory values that can be reliably retrieved in medical records: hematocrit, white blood cells, serum sodium, and creatinine within 24 hours (most abnormal) from the admission.¹³ Admission from another acute care hospital (inter-hospital transfer) was defined as direct transfer from another hospital without transfer to another lower intensity facility. If the patient transferred from another facility with unknown characteristics, that facility was defined as unknown/other facility. Travel time to the nearest VHA primary care physician and VHA hospital was determined from VHA Planning Systems and Support Group (PSSG) geo-coded enrollment files. PSSG calculates distances to the nearest primary and tertiary care VHA sites for all VHA enrolled patients using actual longitude and latitude coordinates of VHA patient residences and nearest VHA facilities. Travel distances are estimated using geospatial technologies that reflects roads and average driving conditions.¹³

Hospital rurality was defined according to the RUCA algorithm and the ZIP code of the facility. Hospital complexity was defined by the VHA as 1 (high resource), 2 (medium resource), and 3 (low resource).²⁴ Hospital COPD-case volume was classified as high (above the median) or low (below the median) based on their total COPD volume during the study period.

Admissions with a missing patient residential rurality classification (n=885) and admissions to VHA hospitals in US territories (ie, Puerto Rico, US Virgin Islands, and American Samoa) were excluded (n=428). We also

excluded admissions to non-acute care VHA hospitals (n= 2,282).

Outcomes

The primary outcome, in-hospital mortality, was defined using the date of death listed in the VHA Vital Status File and the occurrence of this date between the admission and discharge date inclusive. The secondary outcome, 30-day mortality, was defined as the occurrence of death within 30 days from admission.

Statistical Analysis

Unadjusted bivariate analyses were performed to compare patient-level and hospital-level characteristics between urban, rural, and isolated rural veterans using ANOVA test for continuous or chi-square for categorical variables. We compared the admission source between white and black patients using chi-square test to examine whether inter-hospital transfer rates vary between races.

Next, admissions were stratified by race, hospital rurality, COPD hospital-volume, hospital complexity, and admission source. We compared in-hospital mortality in each stratum using the chi-square test. Subsequently, we stratified patient admissions into quartiles by travel time from patient residence to the nearest VHA primary care provider clinic and hospital. Using the Cochran-Armitage trend test, we examined the association of travel time with in-hospital mortality.

In the univariate analysis, we also created logistic regression models with patient and hospital characteristics as the independent variables accounting for repeated admissions and in-hospital ([Supplementary Table 1](#)) and 30-day mortality ([Supplementary Table 2](#)) as the dependent variables. Variables with a P -value ≤ 0.1 in the univariate analysis were considered for the multivariate analysis. To examine which factors can explain the increased mortality in rural patients relative to urban patients, we created several multivariable logistic regression models by adding and removing relevant variables accounting for repeated admissions ([Supplementary Table 3](#)). We also created a logistic regression model with in-hospital mortality as the dependent variable and a logistic regression model with 30-day mortality as the dependent variable adjusted for all the variables that had a P -value ≤ 0.1 in the univariate analysis. Multicollinearity was assessed using pair-wise correlation and weighted regression to assess the information matrix. All statistical analysis were conducted using SAS Enterprise Guide, 2014 SAS Institute Inc.

Results

Of 64,914 total admissions for COPD to 124 VHA hospitals over the study period included in the analysis, 43,549 were from urban (67.1%), 18,673 (28.8%) from rural, and 2,692 (4.1%) from isolated rural areas. Table 1 shows the characteristics of the study cohort, stratified by residence location. In-hospital mortality was 4.9% in urban, 5.5% in rural, and 5.2% in isolated rural veterans admitted with COPD ($P=0.008$). Thirty-day mortality was 8.3% in urban, 9.9% in rural, and 9.2% in isolated rural veterans ($P<0.001$).

Table 2 shows unadjusted in-hospital mortality in urban, rural, and isolated rural veterans stratified by race, hospital location, COPD-case volume, facility complexity, and admission source. White veterans were more likely to be admitted from an acute care hospital (inter-hospital transfer) ($n=2,636$; 5.3%) than black individuals ($n=296$; 2.8%) (Supplementary Table 4). In unadjusted analyses, travel time (Q1 represents the shortest and Q4 the longest travel time) to the nearest VHA primary care provider and hospital was not associated with in-hospital mortality for isolated rural and rural veterans (Figure 1 and Supplementary Table 5). However, travel time to the VHA hospital was associated with increased in-hospital mortality for urban patients in Q1 (<0.001).

In unadjusted analysis, rural residents (but not isolated rural residents) had significantly increased in-hospital mortality relative to the mortality in urban Veterans with an odds ratio (OR) of 1.13 (95% CI=1.04–1.22; $P=0.002$) (Supplementary Table 1). The association of rural residence and in-hospital mortality remained after adjusting for hospital rurality (OR=1.005; 95% CI=1.001–1.01; $P=0.015$) or for hospital COPD-volume (OR=1.005; 95% CI=1.001–1.01, $P=0.010$) (Supplementary Table 3). However, when demographics, ADI, or admission source (inter-hospital transfers) were included in the models, the association of rural residence with in-hospital mortality was no longer present. In the final multivariable logistic regression model that included demographics, ADI, comorbidities, admission source, and hospital characteristics (Figure 2 and Supplementary Table 6), rural residence (OR=0.87; 95% CI=0.67–1.12, $P=0.28$) was not associated with in-hospital mortality. With outpatient admission source as the reference, transfer from another acute care hospital (OR=12.97; 95% CI=9.80–17.16, $P<0.001$) or unknown/other facility (OR=33.05; 95% CI=22.66–48.21,

$P<0.001$) were the strongest predictors of increased in-hospital mortality, whereas obstructive sleep apnea (OR=0.51; 95% CI=0.39–0.67, $P<0.001$) was inversely associated with in-hospital mortality.

In adjusted 30-day mortality analysis (Figure 3 and Supplementary Table 7), rural residence is an independent risk factor for mortality (OR=1.13; 95% CI=1.04–1.22, $P<0.001$). Transfer from another acute care hospital was the stronger predictor of increased 30-day mortality (OR=3.02; 95% CI=2.69–3.39, $P<0.001$), whereas black race (OR=0.73; 95% CI=0.65–0.81, $P<0.001$) and obstructive sleep apnea (OR=0.66; 95% CI=0.61–0.71, $P<0.001$) were inversely associated with 30-day mortality.

Discussion

In a retrospective cohort study of veterans hospitalized with a COPD exacerbation at a VHA hospital, rural veterans but not isolated rural veterans have significantly increased unadjusted in-hospital mortality compared to urban veterans. Rural veterans have higher in-hospital mortality after adjusting for hospital location or hospital volume, but this association with increased mortality goes away after adjusting for demographics, socio-economic level of the residential location, hospital resources, or admission source (where the patient came from). Thus, rural residence does not appear to be an independent risk factor for in-hospital mortality. However, rural residence is an independent risk factor for 30-day mortality, suggesting potential gaps in post-discharge care of rural veterans may contribute to previously reported higher risk of death for rural patients with COPD. Travel time to the nearest VHA primary care provider and hospital among rural veterans was not associated with in-hospital mortality, indicating that the increased mortality is not associated with a potential disparity in access to healthcare. Transfer from another acute-care hospital is strongly associated with increased mortality, while black race is associated with reduced 30-day mortality.

Approximately 19.3% of all Americans reside in rural areas according to the US Census Bureau.²⁸ The age-adjusted death rate for COPD is higher among rural residents than those living in urban areas.²⁹ Among the most common diseases (heart disease, cancer, stroke), COPD is the only one where the mortality gap between rural and urban is increasing. The burden on COPD is even larger in VHA as more than a quarter of Veterans reside in rural areas³⁰ and the prevalence of smoking^{31,32} and COPD is higher among them.^{33–35}

Table I Characteristics of Patients Admitted with a COPD Hospitalization by Residence Location

Variables	Urban (n=43,549)	Rural (n=18,673)	Isolated Rural (n=2,692)	P-value*
Age, Years, Mean±SD	70.4±9.7	71.0±9.0	71.7±9.2	<0.001
Male, n (%)	41,691 (95.7)	18,069 (96.8)	2,602 (96.7)	<0.001
Race, n (%)				<0.001
White	31,054 (71.3)	16,414 (87.9)	2,392 (88.9)	
Black	9,469 (21.7)	986 (5.3)	85 (3.2)	
Other	1,316 (3.0)	597 (3.2)	93 (3.5)	
Missing	1,710 (3.9)	676 (3.6)	122 (4.5)	
Area Deprivation Index, Percentile, Mean±SD	59.3±26.4	66.0±19.6	69.8±16.9	<0.001
Comorbidities, n (%)				
Obstructive sleep apnea	16,318 (37.5)	6,905 (37.0)	957 (35.6)	0.090
Diabetes	9,023 (20.7)	4,201 (22.5)	588 (21.8)	<0.001
Congestive heart failure	7,947 (18.3)	3,461 (18.5)	524 (19.5)	0.23
Pneumonia	22,932 (52.7)	10,417 (55.8)	1,411 (52.4)	<0.001
Hypertension	5,399 (12.4)	2,410 (12.9)	335 (12.4)	0.21
Peripheral vascular disease	4,357 (10.0)	2,006 (10.7)	289 (10.7)	0.02
Cancer	4,854 (11.2)	2,028 (10.9)	287 (10.7)	0.47
Coronary artery disease	3,890 (8.9)	1,797 (9.6)	282 (10.5)	0.002
Chronic kidney disease	4,351 (10.0)	1,743 (9.3)	244 (9.1)	0.02
Stroke	556 (1.3)	206 (1.1)	34 (1.3)	0.19
Liver Disease	2,069 (4.8)	632 (3.4)	70 (2.6)	<0.001
Rheumatoid arthritis	541 (1.2)	264 (1.4)	70 (2.6)	<0.001
Ulcer	518 (1.2)	266 (1.4)	38 (1.4)	0.044
Acquired immunodeficiency syndrome	201 (0.5)	25 (0.1)	1 (0.0)	<0.001
Dementia	602 (1.4)	177 (1.0)	33 (1.2)	<0.001
Admission Source, n (%)				<0.001
Outpatient	39,756 (91.4)	16,533 (88.6)	2,409 (89.5)	
Acute care hospital	1,688 (3.9)	1,304 (7.0)	174 (6.5)	
Nursing Home	980 (2.3)	327 (1.8)	29 (1.1)	
Unknown/Other Facility	1,125 (2.6)	509 (2.7)	80 (3.0)	
Travel Time to VA Minutes, Median (IQR)				
Primary Care Provider	12 (8–18)	29 (18–41)	43 (31–72)	<0.001
Hospital	16.3 (8.8–30.7)	55.4 (34.0–83.9)	85.8 (57.2–120.6)	<0.001
Hospital Location, n (%)				<0.001
Rural	364 (0.8)	2,322 (12.4)	448 (16.6)	
Urban	43,185 (99.2)	16,351 (87.6)	2,244 (83.4)	
COPD-case Volume, n (%)				<0.001
Low	7,400 (17.0)	3,879 (20.8)	861 (32.0)	
High	36,149 (83.0)	14,794 (79.2)	1,831 (68.0)	
Hospital Complexity, n (%)				<0.001
High resource	40,206 (92.3)	15,191 (81.4)	1,842 (68.4)	
Medium resource	2,028 (4.7)	2,067 (11.1)	501 (18.6)	
Low resource	1,315 (3.0)	1,415 (7.6)	349 (13.0)	
Labs, Mean±SD				
Hematocrit%	39.0±6.2	39.0±6.2	39.2±6.1	0.197
WBC, 10 ⁹ cells per L	10.0±4.9	10.5±5.1	10.7±5.3	<0.001
Sodium, mmol/L	137.7±4.8	137.6±4.7	137.7±4.5	0.053

(Continued)

Table 1 (Continued).

Variables	Urban (n=43,549)	Rural (n=18,673)	Isolated Rural (n=2,692)	P-value*
Blood Urea Nitrogen, mg/dL	22.6±19.9	23.3±19.3	23.1±18.6	0.001
Creatinine, mg/dL	1.3±1.1	1.2±1.0	1.2±0.9	<0.001
Mortality, n (%)	2,150 (4.9)	1,033 (5.5)	141 (5.2)	0.008
30-day Mortality, n (%)	3,604 (8.3)	1,841 (9.9)	247 (9.2)	<0.001

Notes: *ANOVA for continuous and chi-square for categorical variables; Low and high COPD-case volume hospitals were defined as hospitals with the annual rate of COPD admissions below and above the median.

Table 2 Unadjusted in-Hospital Mortality for Rural and Urban Residing Veterans Stratified by Hospital Rurality, Volume, Complexity, and Admission Source

		Urban (n=43,549)	Rural (n=18,673)	Isolated Rural (n=2,692)	P-value
Hospital Rurality					
Rural Hospital	n=3,134	27 (7.4%)	135 (5.8%)	31 (6.9%)	0.38
Urban Hospital	n=61,780	2,123 (4.9%)	898 (5.5%)	110 (4.9%)	0.016
COPD Volume					
Low	n=12,140	508 (6.9%)	289 (7.5%)	52 (6.0%)	0.27
High	n=52,774	1,642 (4.5%)	744 (5.0%)	89 (4.9%)	0.058
Hospital Complexity					
1 (High)	n=57,329	1,818 (4.5%)	787 (5.2%)	94 (5.1%)	0.004
2 (Medium)	n=4,596	178 (8.8%)	136 (6.6%)	27 (5.4%)	0.005
3 (Low)	n=3,079	154 (11.7%)	110 (7.8%)	20 (5.7%)	<0.001
Admission source					
Outpatient	n=58,698	1,024 (2.6%)	505 (3.1%)	70 (2.9%)	0.006
Acute Care Hospital	n=3,166	603 (35.7%)	289 (22.2%)	42 (24.1%)	<0.001
Nursing Home	n=1,336	79 (8.1%)	33 (10.1%)	3 (10.3%)	0.50
Unknown/Other Facility	n=1,714	444 (39.5%)	206 (40.5%)	26 (32.5%)	0.40
Race					
White	n=49,860	1,666 (5.4%)	892 (5.4%)	130 (5.4%)	0.95
Black	n=10,504	278 (2.9%)	41 (4.2%)	3 (3.5%)	0.10
Other	n=2,006	60 (4.6%)	43 (7.2%)	4 (4.3%)	0.053
Missing	n=2,508	146 (8.5%)	57 (8.4%)	4 (3.3%)	0.12

Notes: Chi-square was used for comparisons between groups. Low and high COPD-case volume hospitals were defined as hospitals with the rate of COPD admissions during the study period being below and above the median.

Environmental factors have been implicated as potential causes of observed rural–urban disparities, with agriculture-related exposure being associated with COPD exacerbations.^{12,36} However, European studies suggest that agriculture exposure may be protective.^{37,38} Higher prevalence of comorbidities in rural patients may also be responsible for rural–urban disparities in COPD.²⁹ Our findings confirm that after adjusting for demographics and comorbidities, patient residence was not associated with in-hospital mortality.

The association of obstructive sleep apnea with lower mortality in our cohort seems counter-intuitive with a first

glance because obstructive sleep apnea is a known risk factor for mortality.³⁹ Nevertheless, obstructive sleep apnea may indicate misdiagnosis of hypercapnic respiratory failure due to obesity hypoventilation syndrome which is associated with relatively low short-term mortality^{40–42} and lower than that in COPD-related respiratory failure.⁴³ Another paradoxical finding is the association of pneumonia with reduced 30-day mortality. We have no good explanation of that but we could assume that the co-existing pneumonia may be confounded by early administration of antibiotic use which is associated with improved outcomes in COPD.⁴⁴

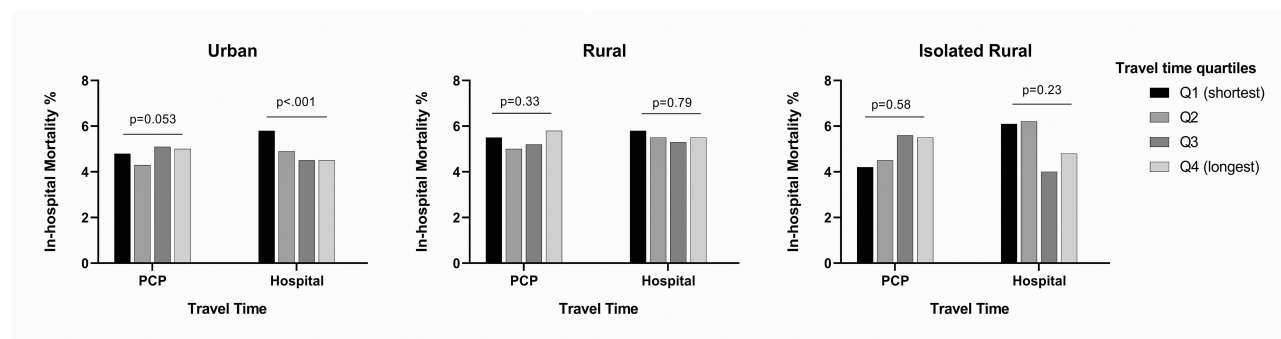


Figure 1 Unadjusted in-hospital mortality by travel time to the nearest Veterans Health Administration primary care provider and hospital. In-hospital mortality between quartiles was compared by Cochran-Armitage Trend Test.

Abbreviations: PCP, primary care physician; Q1, first (shortest travel time) quartile; Q2, second quartile; Q3, third quartile; Q4, fourth (longest travel time) quartile.

Race is another important factor that may affect COPD outcomes. Although black race is considered a risk factor for developing COPD,⁴⁵ COPD-related death rates in black patients are lower than the rates in white individuals.⁴⁶ The effect of race on COPD outcomes is unclear.^{47–51} Prior research from our group has shown that black individuals are more likely to receive mechanical ventilation for COPD exacerbation than white veterans.⁵² The protective effect of black race may also be confounded by the inter-hospital transfers. We observed fewer black than white individuals transferred from another acute care facility, and inter-hospital transfer was the strongest risk factor for mortality.

A disparity in access to healthcare is a potential reason for rural–urban disparities. In a non-VA study, a pulmonologist was available within a 10-mile distance for only 35% of rural areas in the US¹⁴ with pulmonary specialist availability being associated with reduced emergency room and hospital visits.⁵³ Early follow-up with a pulmonologist after hospital discharge has been shown to reduce COPD-related re-admissions.⁵⁴ Although a primary care physician is usually available within a 10-mile distance in rural areas and almost all individuals had access to one within 50 miles,¹⁴ there are concerns that rural and remote healthcare practitioners may lack the knowledge, experience, and confidence to manage COPD patients according to a survey conducted by the Australian Lung Foundation.⁵⁵ A study from the Minneapolis VHA HealthCare System though showed while fewer patients had spirometries in rural clinics, COPD-related quality metrics including immunizations and medication prescriptions were similar between rural and urban clinics.⁵⁶

We extended the literature by showing a lack of association between travel time to the nearest VHA primary

care provider/hospital and in-hospital mortality, suggesting that delays to access of care cannot explain the increased mortality in rural patients with COPD. On the other hand, urban veterans who reside close to a VHA hospital had increased in-hospital mortality. There are several potential reasons for this, including ambulance transfer patterns for the sickest patients, socio-economic factors, or patients with longer travel time to the nearest VHA hospital may have sought care in non-VHA facilities and we did not capture them in the analysis.⁵⁷ Likely for the same reason, we observed mortality rates in isolated rural veterans were between the mortality rates in urban and rural patients, respectively.

The increased in-hospital mortality in rural veterans compared to the mortality in urban veterans is likely confounded by inter-hospital transfers. Inter-hospital transfers increase mortality because they may result in delays in receiving appropriate care, such as antibiotics and initiating non-invasive mechanical ventilation. These delays are associated with increased COPD-related hospital mortality.^{44,58} Moreover, patients requiring transfers are likely sicker than those not transferred.

Hospital volume may also play a role in the care of COPD patients. Earlier studies have shown that admission to a high volume hospital is associated with favorable outcomes in COPD,⁵⁹ but a recent study showed no association.⁶⁰ Improvement in care of COPD and widespread use of non-invasive ventilation, which is the most effective treatment for COPD respiratory failure and can be available in almost every hospital, may explain this.¹⁶ In our study, COPD-volume did not seem to affect mortality.

In addition, our findings suggest potential gaps in post-discharge care of rural veterans as rural residence is an

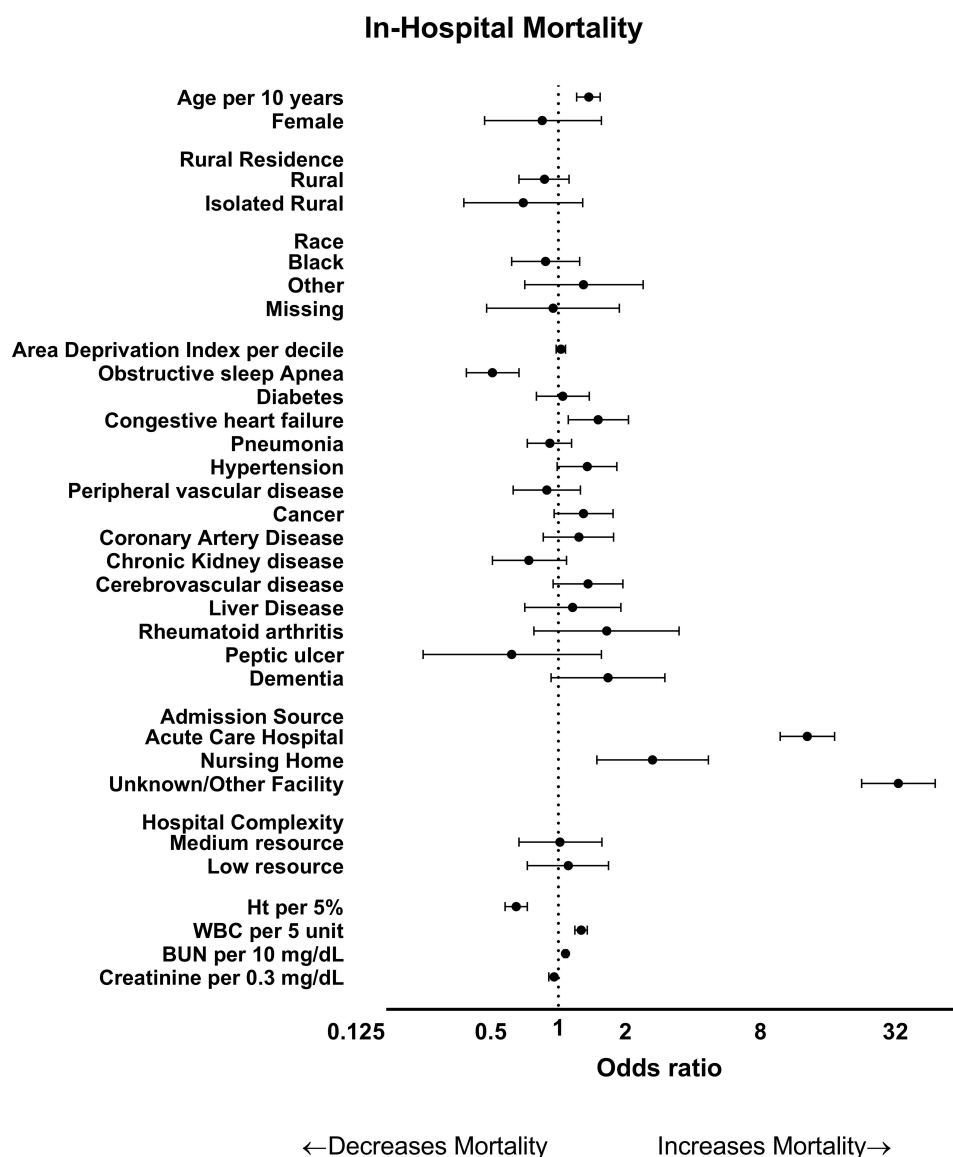


Figure 2 Multivariable logistic regression model for in-hospital mortality. Odds ratio with 95% confidence intervals are shown (x-axis) on log scale with base of 2. Low COPD-case volume hospitals were defined as hospitals with the annual rate of COPD admissions below the median.

independent risk factor for 30-day mortality but not for in-hospital mortality. Rural patients may not have access to pulmonary rehabilitation or even to their primary care physician, when patients are recovering from acute illness.

This study has limitations that should be considered. It was conducted in a single healthcare system with a predominantly male population. In addition, our study did not take into consideration Veterans who did not use the VHA for their medical care. Therefore, our findings may not be generalizable outside of the VHA. We did not have smoking exposure data. Because we did not have spirometric data, we cannot confirm the diagnosis of COPD or adjust for lung function severity.

Nevertheless, we validated the diagnostic accuracy of ICD codes using spirometric and radiographic data from one site (our hospital). Comorbidities and age, which were used in our models, are also associated with spirometric COPD.¹⁹ We do not have data regarding causes of death. Moreover, we used only data for patients admitted to VHA hospitals. Rural veterans may be hospitalized at civilian hospitals more often than urban veterans due to travel distances and convenience. Conditions like pneumonia may mimic COPD exacerbation but it is unlikely that patients with pneumonia were misdiagnosed with COPD because pneumonia would be associated with increased mortality which was not observed.⁶¹ We did

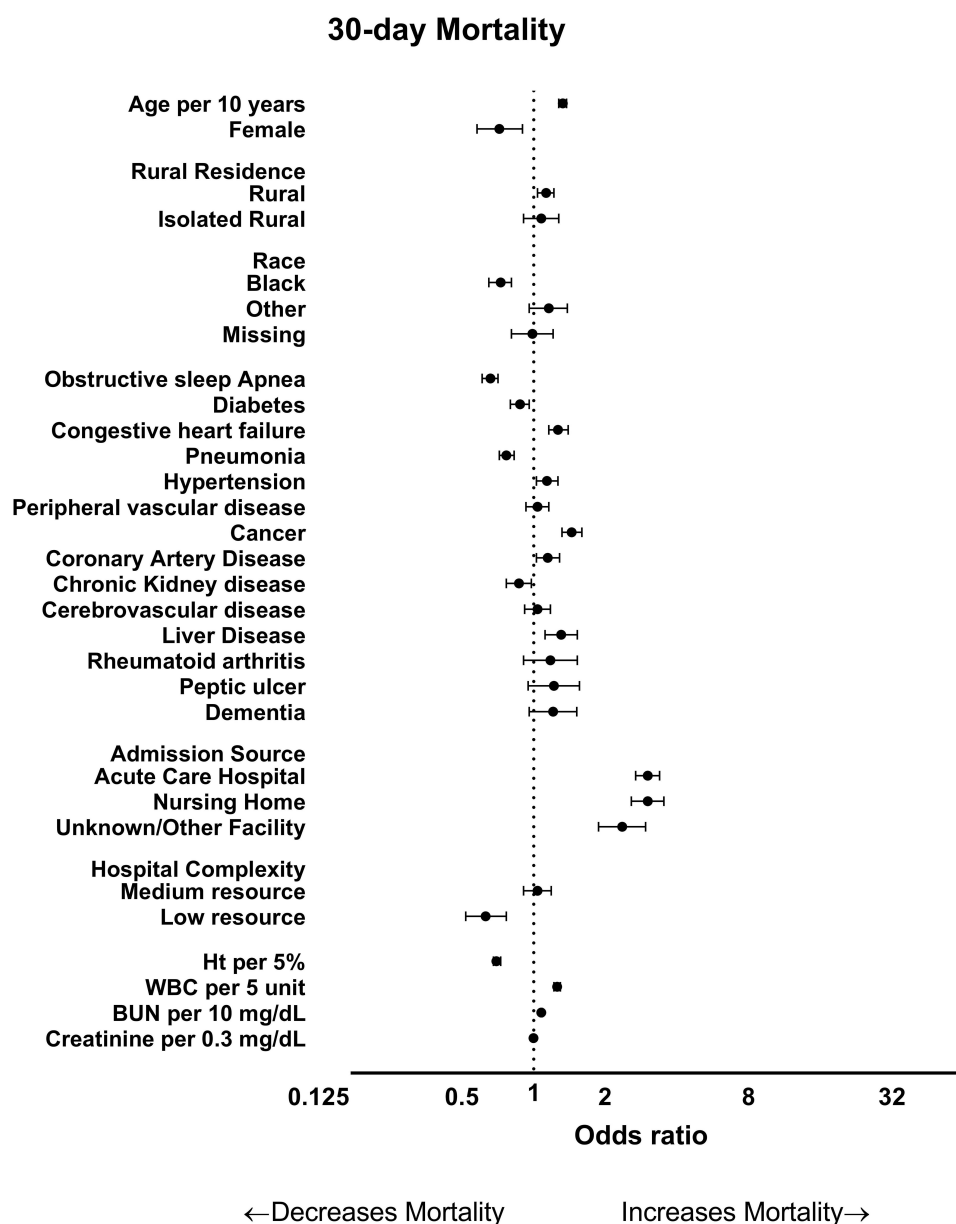


Figure 3 Multivariable logistic regression model for 30-day mortality. Odds ratio with 95% confidence intervals are shown (x-axis) on log scale with base of 2. Low COPD-case volume hospitals were defined as hospitals with the annual rate of COPD admissions below the median.

not consider physiological parameters like partial pressure of CO₂ in the arterial blood which indicate the severity of the patients on the admission. However, we would expect that if rural patients were sicker on admission due to longer time to reach a VHA hospital, we would have seen an increased mortality in those who live in the most remote areas. We did not include laboratory variables like serum bicarbonate which may provide prognostic information as we have no reliable way to capture them in all the facilities. In addition, we did not examine adherence of interventions known to be

associated with favorable outcomes (eg, antibiotic or non-invasive ventilation use).^{44,58}

Conclusions

Rural residence is not an independent risk factor for in-hospital mortality, but it is associated with increased 30-day mortality after hospitalization due to COPD exacerbation suggesting potential gaps in post-discharge care of rural veterans. Further, travel time to the nearest primary care physician and hospital is not associated with in-hospital mortality. Inter-hospital transfer is the stronger

predictor of increased in-hospital mortality. Further research should investigate the exact mechanism that inter-hospital transfers affect mortality.

Abbreviations

ADI, Area Deprivation Index; CDC, center of disease control; COPD, chronic obstructive pulmonary disease; ICD-9-CM and ICD-10-CM, International Classification of Diseases, Ninth and Tenth Revisions, Clinical Modification; OR, odds ratio; RUCA, rural urban commuting area; VHA, Veterans Health Administration.

Acknowledgments

The views expressed in this article are those of the authors and do not necessarily reflect the position or policy of the Department of Veterans Affairs or the United States Government.

Author Contributions

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Obtained funding: Spyridon Fortis.

Spyridon Fortis had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

All authors made substantial contributions to the conception and design, acquisition of data, or analysis and interpretation of data; took part in drafting the article or revising it critically for important intellectual content; agreed to submit to the current journal; gave final approval of the version to be published; and agree to be accountable for all aspects of the work.

Funding

The work reported here was supported by the Department of Veterans Affairs, Veterans Health Administration, Office of Rural Health, Veterans Rural Health Resource Center (Award # 14380), and the Health Services Research and Development (HSR&D) Service through the

Comprehensive Access and Delivery Research and Evaluation (CADRE) Center (CIN 13-412).

Disclosure

Dr Fortis reports grants from Office of Rural Health, during the conduct of the study; has received grants from American Thoracic Society and Fisher & Paykel to study the effect of heat humidified high flow air on COPD and has consulted Genentech in a study examining the effect of omalizumab on obstructive lung disease. Alejandro Comellas reports grants from NIH, personal fees from GSK Consultant, and non-financial support from VIDA, outside the submitted work. The authors report no other potential conflicts of interest for this work.

This paper was presented at the Virtual American Thoracic Society Conference name as a poster presentation/conference talk with interim findings. The poster's abstract was published in "Poster Abstracts" in American Journal of Respiratory and Critical Care Medicine 2020;201:A4581 <https://doi.org/10.1164/ajrccm-conference.2020.201.1.MeetingAbstracts.A4581>.

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