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## Spatial Analysis of Health Care Utilization among Medicare Beneficiaries with Coal Workers' Pneumoconiosis and Other Related Pneumoconiosis

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## Spatial Analysis of Health Care Utilization among Medicare Beneficiaries with Coal Workers' Pneumoconiosis and Other Related Pneumoconiosis

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### Overview of Key Findings

- The states with the highest number of Medicare beneficiaries with coal workers' pneumoconiosis (CWP) were Kentucky, West Virginia, Virginia, and Pennsylvania.
- Significant clustering of health care utilization rates for Medicare beneficiaries with CWP was observed in the central Appalachian states of Kentucky, West Virginia, and Virginia.
- Significant clustering of health care utilization rates for Medicare beneficiaries with Other Related Pneumoconiosis was observed in Appalachia and the southeast parts of Texas and Louisiana. This clustering merits additional research to understand underlying disease etiology.

### Introduction

The United States generates 30% of its electricity needs from coal.<sup>1</sup> Seventy percent of coal is produced in five states: Wyoming (41%), West Virginia (11%), Kentucky (6%), Illinois (6%), and Pennsylvania (6%).<sup>2</sup> In 2017, approximately 50,000 workers were employed in coal mining jobs in the U.S.<sup>3</sup> Over half of coal mining jobs are concentrated in just 25 mostly rural counties spread over 9 states.

### Occupational Lung Diseases among Coal Miners

Workers employed in the mining industry are at risk of developing respiratory diseases such as Chronic Obstructive Pulmonary Disease (COPD), asbestosis, silicosis, and coal workers' pneumoconiosis (CWP), also referred to as black lung disease. CWP is a progressive occupational lung disease caused by overexposure to respirable coal mine dust.<sup>4-6</sup> Inhaled dust particles deposit deep in the lung parenchyma causing inflammation, fibrosis, and premature death.<sup>4-6</sup> There is no cure for CWP.

Due to Federal restrictions placed on respirable dust concentrations in underground coal mines in 1969, the prevalence of CWP has declined from 11% in the 1970s to 4% in 2005-2015.<sup>7</sup> However, recent studies have suggested the rising prevalence of its severe form—progressive massive fibrosis (PMF)—especially in the central Appalachian region comprising Kentucky, Virginia, and West Virginia.<sup>7,8</sup>

The Federal Coal Mine Health and Safety Act of 1969 outlined practices to improve the health of all individuals working in underground coal mines, such as mandating the mine to offer a chest X-ray every five years to all workers. Additionally, there exist speciality Black Lung clinics throughout the U.S. that provide educational, screening, diagnostic, treatment, and benefits counseling services to current and former coal miners.

## Health Care Utilization

Health care utilization quantifies the use of health care services such as office visits, emergency room visits, and hospitalization for prevention or maintenance of health.<sup>9</sup> Health care utilization data are used for several purposes including comparing the cost of services, assessing health care delivery, and comparing utilization rates among subgroups.<sup>9</sup> The most common source of health care utilization data is administrative claims data. Administrative claims data include insurance claims and payment information. These are essentially payment records for inpatient or outpatient visits to health care providers. The payments are made based on the ICD-9 or ICD-10 diagnosis coding.

Medicare claims data are the largest source of health care utilization data in the U.S., covering over 97% of adults 65 years and older.<sup>10</sup> There are more than 50 million beneficiaries enrolled in Medicare. About 16% of Medicare beneficiaries are disabled, of whom 4.6% are less than 65 years old.<sup>11,12</sup>

## Geographical Mapping & Cluster Analysis

A Geographic Information System (GIS) is a computer-based tool to collect, store, manipulate, analyze, and display, usually in a map, geographical data.<sup>13</sup> Rapid advancement in computing technology and availability of GIS software has made increasing use of GIS in health care and the public health discipline possible.<sup>13</sup> Geographical mapping software can take spatial and non-spatial data from multiple sources and integrate them in such a way that allows users to summarize, simplify, and visualize complex patterns and anomalies in data. These complex geographical or spatial patterns are quantified using spatial cluster analysis. Spatial cluster analysis is a process of grouping observations into clusters. The process then measures the degree of similarity between observations within clusters under the assumption that nearby observations are more related (similar) than distant observations.<sup>14,15</sup> Spatial cluster analysis has been used by researchers to analyze health care access and utilization data.<sup>16-18</sup>

There is little information available on geographical distribution and spatial clustering of health care utilization among Medicare beneficiaries with CWP and Other Related Pneumoconiosis. Hence, this project aimed to:

1. Determine and map the geographical distribution of health care utilization patterns among Medicare beneficiaries with CWP (ICD-9-CM 500) and Other Related Pneumoconiosis (ICD-9-CM 501-505) using the Medicare beneficiaries Limited Data Set (LDS) from 2011-2014, and
2. Conduct spatial analysis of health care utilization among Medicare beneficiaries with CWP and Other Related Pneumoconiosis.

## Methods

### Data

We used Medicare LDS and administrative claims data for this study. The LDS is a random sample of 5% of the Medicare population. Data on discharge diagnosis of CWP and other related pneumoconiosis were obtained from the 5% sample Medicare LDS for the years 2011 to 2014. Patients with a diagnosis of ICD-9-CM 500 (CWP) and ICD 501-505 (Other Related Pneumoconiosis Diseases) were included in this analysis (Table 1). Patients were initially selected from the inpatient and carrier files using the study period of January 1, 2011, through December 31, 2014. The date of first diagnosis of CWP served as the patient's index date. If the patient did not have a diagnosis of CWP then the date of the first diagnosis of asbestosis, pneumoconiosis due to other silica or silicates, pneumoconiosis due to other inorganic dust, pneumonopathy due to inhalation of other dust or pneumoconiosis, or unspecified pneumoconiosis served as the index date.

Patients were followed from the first observable diagnosis of CWP to death or censorship. Some demographic and clinical characteristics included in the Medicare data were sex, age, geographic region, race/ethnicity, primary payer, elixhauser comorbidities, and chronic lung disease comorbidities. A total of 8,713 beneficiaries met all study inclusion criteria based on the diagnosis codes. We excluded 88 patients from the spatial clustering analysis. These included 22 beneficiaries whose residence was outside the contiguous United States and 66 beneficiaries (13 with CWP and 53 with Other Related Pneumoconiosis) whose county information was not available. The total that remained for this analysis was 8,625 beneficiaries.

**Table 1. ICD-9-CM Diagnosis Codes for CWP and Other Related Pneumoconiosis**

ICD-9-CM Code	Description
500	Coal workers' pneumoconiosis
501	Asbestosis
502	Pneumoconiosis due to other silica or silicates
503	Pneumoconiosis due to other inorganic dust
504	Pneumonopathy due to inhalation of other dust
505	Pneumoconiosis, unspecified

### *Determining the Rate of Utilization*

We calculated total counts for utilization for Medicare beneficiaries with CWP or Other Related Pneumoconiosis by summing (a) office visits, (b) emergency room visits, and (c) hospitalizations at the county level. The resulting total was divided by the population of Medicare beneficiaries in the county (N) to compute a four-year rate of health care utilization (U).

$$U = \left( \frac{a + b + c}{N} \right) * 1,000$$

Where,

U = Four-year rate of utilization

a = office visits, b = emergency room visits, c = hospitalizations

N = the population of Medicare beneficiaries in the county

### *Analysis*

The county-level individual counts and rate of health care utilization of Medicare beneficiaries with CWP and Other Related Pneumoconiosis as the discharge diagnosis were calculated and mapped using ArcGIS v10.5 (ESRI, Redlands, CA). Furthermore, we used cluster-outlier analysis to determine counties with significantly high clustering of health care utilization for CWP and Other Related Pneumoconiosis. This analysis identifies spatial clusters of features with high or low values and outliers.<sup>15,19</sup> To achieve these results, the methodology calculates a local Moran's I value (spatial autocorrelation statistic), a z-score, a pseudo *P* value, and a code representing the cluster type for each statistically significant feature. The null hypothesis for the Moran's I spatial autocorrelation test is that the data are randomly distributed. The alternate hypothesis is that the data are more spatially clustered than expected by chance alone. The z-scores and pseudo *P* values represent the statistical significance of the computed index values.<sup>19</sup>

### *Findings*

From 2011 to 2014, we observed 1,657 patients and 35,771 total health care utilization among Medicare beneficiaries with CWP as a discharge diagnosis. About 30.1% of health care utilization was for emergency

visits, 9.7% represented hospitalizations, and the remaining 60.2% represented office visits. In addition, 6,968 patients and 152,171 total health care utilization with Other Related Pneumoconiosis (asbestosis, pneumoconiosis due to other silica or silicates, pneumoconiosis due to other inorganic dust, pneumonopathy due to inhalation of other dust or pneumoconiosis, or unspecified) as the discharge diagnosis were observed. About 32.7% of health care utilization with Other Related Pneumoconiosis (ICD-9-CM 501-505) as the diagnosis was emergency visits, 10% represented hospitalizations, and the remaining 57.2% represented office visits. Consequently, we observed 103 patients and 6,085 total health care utilization with CWP and Other Related Pneumoconiosis during the study period. For both CWP and Other Related Pneumoconiosis as the discharge diagnosis, the individual was most likely to be male, white, and 65+ years old during the study period. Almost a quarter of Medicare beneficiaries with CWP were under 65 years old as compared to 7% of Medicare beneficiaries with Other Related Pneumoconiosis (Table 2).

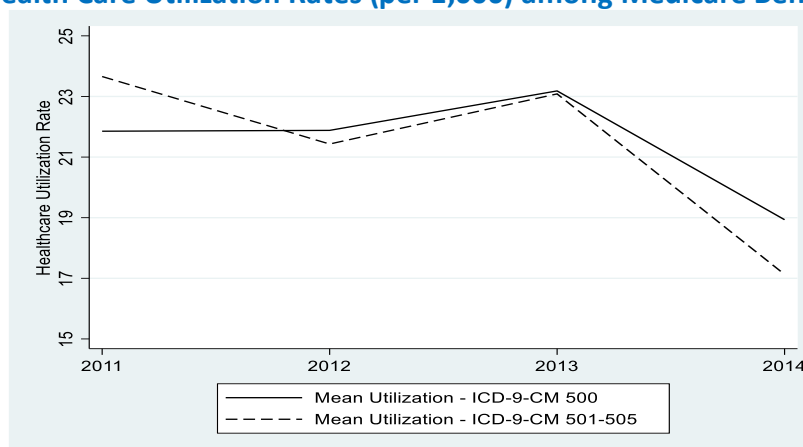
**Table 2. Demographic Characteristics of Medicare Beneficiaries with CWP and Other Related Pneumoconiosis in Medicare LDS Claims Data from 2011 to 2014.**

Individual characteristic	CWP		Other Related Pneumoconiosis	
	Patients (N = 1,657)	Total Utilization (N = 35,771)	Patients (N = 6,968)	Total Utilization (N = 152,171)
	n (%)	n (%)	n (%)	n (%)
<b>Gender</b>				
Male	1,300 (78)	28,392 (79)	6,175 (89)	133,774 (88)
Female	357 (22)	7,379 (21)	793 (11)	18,397 (12)
<b>Age group</b>				
<= 64	374 (23)	9,033 (25)	511 (7)	14,248 (9)
65 and older	1,283 (77)	26,738 (75)	6,457 (93)	137,923 (91)
<b>Race<sup>a</sup></b>				
White	1,481 (90)	31,728 (89)	6,261 (91)	135,693 (90)
Black	110 (7)	2,935 (8)	490 (7)	11,968 (8)
Other	53 (3)	854 (2)	154 (2)	3,186 (2)

<sup>a</sup>Race information was missing on 76 Medicare beneficiaries.

The average health care utilization rates among Medicare beneficiaries with CWP ranged between 19.3 per 1,000 in 2014 to 21.7 per 1,000 in 2011. The rates among beneficiaries with Other Related Pneumoconiosis were similar (Figure 1).

**Figure 1. Average Health Care Utilization Rates (per 1,000) among Medicare Beneficiaries by Year.**



The counts and health care utilization rates of Medicare beneficiaries are displayed in Figures 2A and 2B, respectively. More than half of the cases of CWP were concentrated in four central Appalachian states: Kentucky, West Virginia, Virginia, and Pennsylvania (Table 3). The average health care utilization in these four states ranged from as low as 15 per 1,000 in Pennsylvania to as high as 276 per 1,000 in West Virginia.

**Table 3. Counts, Percentages, and Health Care Utilization Rates (per 1,000) of Medicare Beneficiaries with CWP in Medicare LDS Claims Data from 2011 to 2014.**

State	CWP (N=1,657)		Health Care Utilization Rates per 1,000
	n	%	Mean
Kentucky	320	19.3	185
West Virginia	285	17.2	276
Virginia	163	9.8	66
Pennsylvania	102	6.2	15

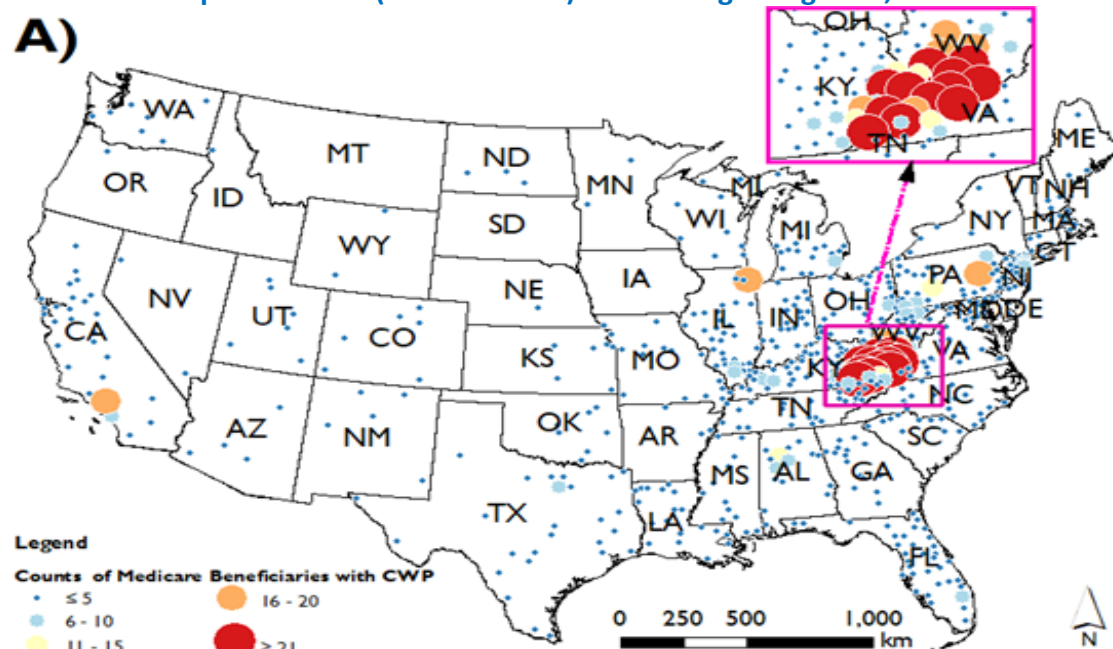
The distribution of CWP and health care utilization rates for counties in these four states varied considerably. In Kentucky half of the CWP cases were concentrated in five counties: Pike, Harlan, Letcher, Floyd, and Perry. And the health care utilization rates varied from a low of 946 per 1,000 in Perry County to a high of 3,038 per 1,000 in Letcher County.

In West Virginia, Raleigh, Wyoming, Mercer, Logan, McDowell, and Fayette counties accounted for over half of CWP cases. The health care utilization rates in these counties varied from a high of 1,389 per 1,000 in Wyoming County to a low of 456 per 1,000 in Mercer County.

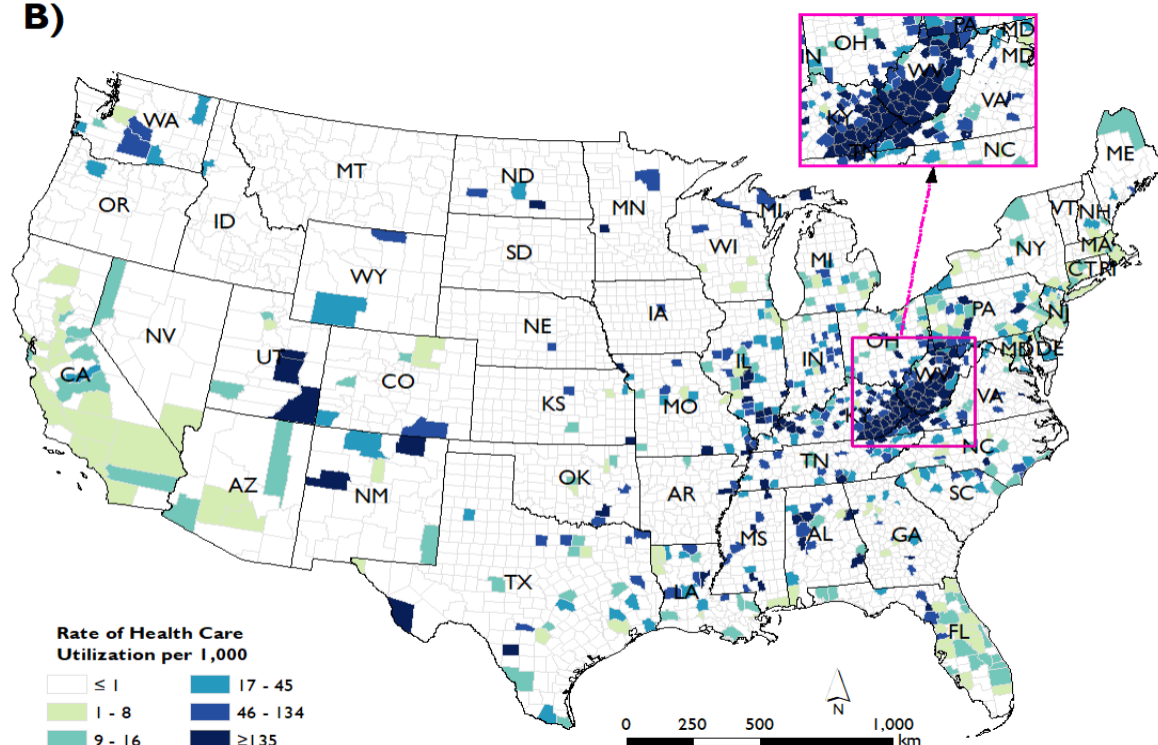
In Virginia, almost 60% of CWP cases were reported in Buchanan, Wise, Tazewell, and Dickerson counties. The health care utilization rates in these counties were highest in Dickerson County (2,211 per 1,000) and lowest in Tazewell County (1,354 per 1,000).

Lastly, more than 60% of CWP cases in Pennsylvania were concentrated in Schuylkill (health care utilization rate of 248 per 1,000) and Cambria (health care utilization rate of 177 per 1,000) counties.

**Figure 2. Four-Year County-Level Counts of Medicare Beneficiaries and Rate of Health Care Utilization Maps with CWP (ICD-9-CM 500) as Discharge Diagnosis, 2011-2014.**





**B)**

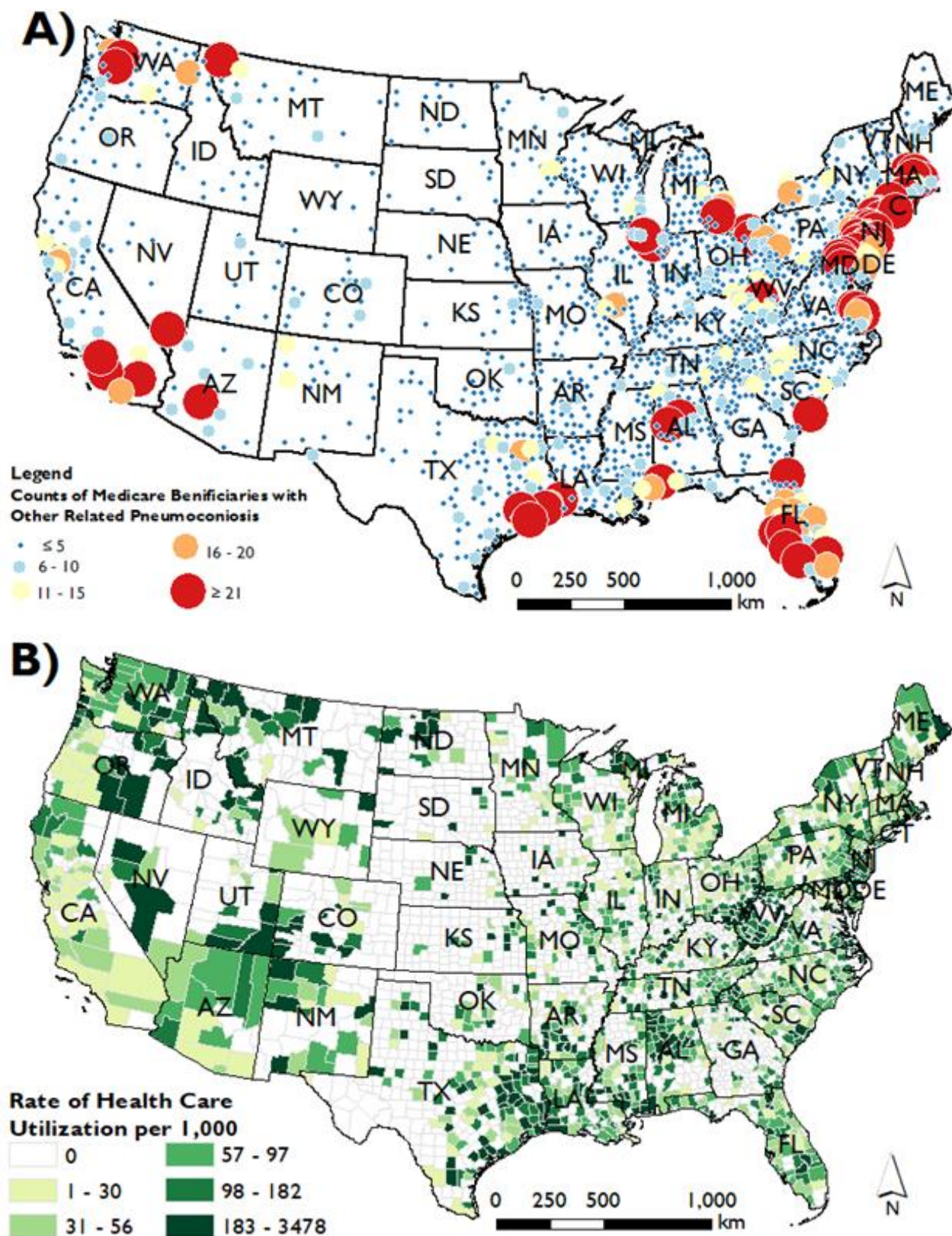
The counts and health care utilization rates of Medicare beneficiaries with Other Related Pneumoconiosis are shown in Figures 3A and 3B, respectively. A quarter of the cases were concentrated in four states: Florida, Texas, New Jersey, and New York (Table 4, Figure 3A), and rates of health care utilization in these states were 60, 63, 138, and 61, respectively (Table 4). However, the highest rates of utilization were observed in West Virginia (201 per 1,000), Montana (182 per 1,000), and Delaware (156 per 1,000).

**Table 4. Counts, Percentage, and Health Care Utilization Rates (per 1,000) of Medicare Beneficiaries with Other Related Pneumoconiosis in Medicare LDS Claims Data from 2011 to 2014.**

State	Other Related Pneumoconiosis (N=6,968)		Health Care Utilization Rate per 1,000
	n	%	Mean
Florida	481	6.9	60
Texas	479	6.9	63
New Jersey	439	6.3	138
New York	408	5.9	61



**Figure 3. Four-Year County-Level Counts of Medicare Beneficiaries and Rate of Health Care Utilization Maps with Other Related Pneumoconiosis (ICD-9-CM 501–505) as Discharge Diagnosis, 2011–2014.**

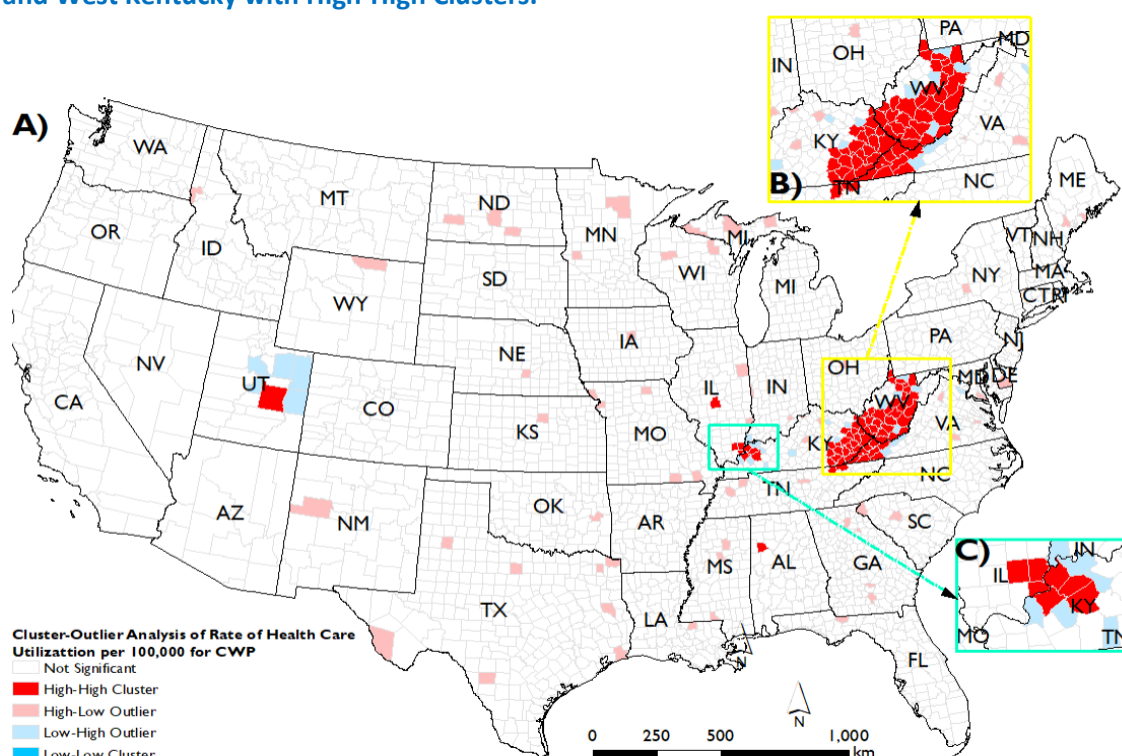


### Spatial Clustering Analysis of Rate of Health Care Utilization

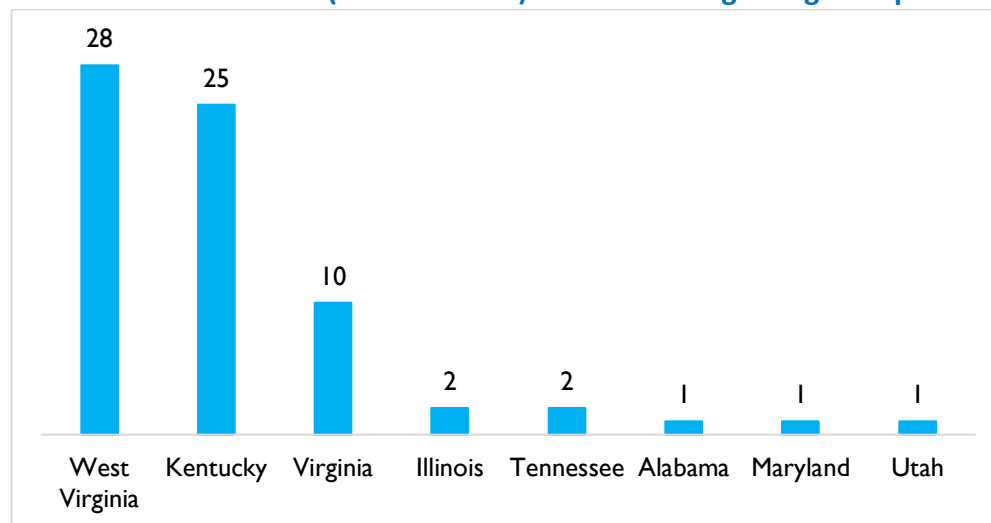
Spatial clustering techniques such as cluster-outlier analysis identify statistically significant ( $P < .05$ ) clusters of high and low values based on the rate of health care utilization per each county as derived from modeling the spatial relationship among the counties. The results of this spatial clustering technique produce five main categories of clusters. These are the High-High cluster, High-Low outlier, Low-High outlier, Low-Low cluster, and Not Significant cluster types. High-High cluster means counties with high rates of health care utilization for Medicare beneficiaries are significantly near or surrounded by neighboring counties with high rates of utilization. High-Low outlier means counties with high rates of health care utilization by beneficiaries are significantly near or surrounded by neighboring counties with low rates of utilization. Low-high outlier means counties with low rates of health care utilization by beneficiaries are significantly near or surrounded by neighboring counties with high rates of utilization. Low-low cluster means counties with low rates of health care utilization by beneficiaries are significantly near or surrounded by neighboring counties with low rates of utilization. Not significant cluster type means the pattern for the spatial relationship is not significantly different from a random pattern.

The spatial clustering analysis for rates of health care utilization for Medicare beneficiaries with CWP diagnosis (Figure 4A) showed two major clusters in the contiguous U.S. (Figures 4B and 4C). There was statistically significant ( $P < .05$ ) clustering of health care utilization rates in 63 counties in Kentucky, Virginia, and West Virginia (Figure 4B). A smaller cluster of five counties was present in the west of Kentucky (Union, Webster, and Crittenden Counties) and south of Illinois (Gallatin and Hardin Counties) (Figure 4C). West Virginia ( $n = 28$ ) and Kentucky ( $n = 25$ ) reported the largest number of counties with significantly high rates of health care utilization for Medicare beneficiaries with CWP as compared to other states in the country (Figure 5).

**Figure 4. Spatial Clustering Analysis of Four-Year Rate of Health Care Utilization for Medicare Beneficiaries with CWP (ICD-9-CM 500) as the Discharge Diagnosis, 2011-2014.**  
**A) Overview in the U.S., B) Insert Map Showing an Area in Central Appalachia, C) Counties Bordering Illinois and West Kentucky with High-High Clusters.**

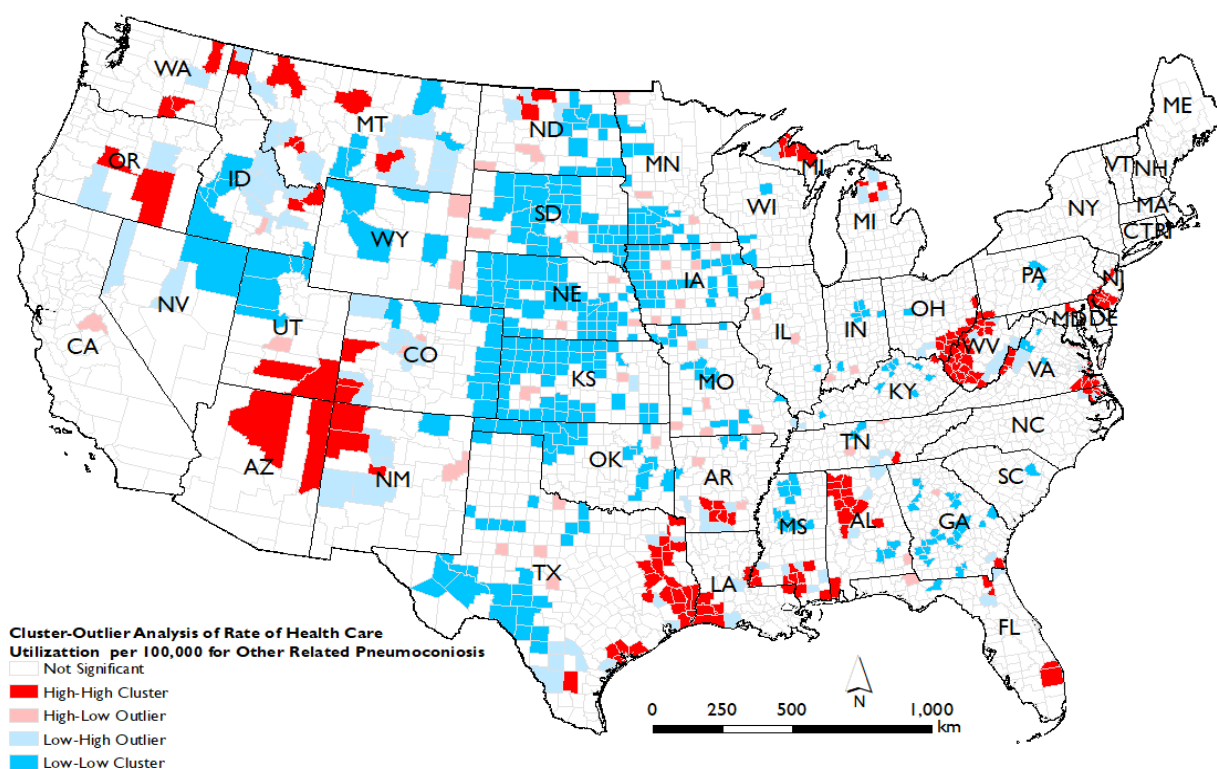


**Figure 5. Number of Counties with Significantly High Rates of Health Care Utilization for Medicare Beneficiaries with CWP (ICD-9-CM 500) as the Discharge Diagnosis per State, 2011-2014.**



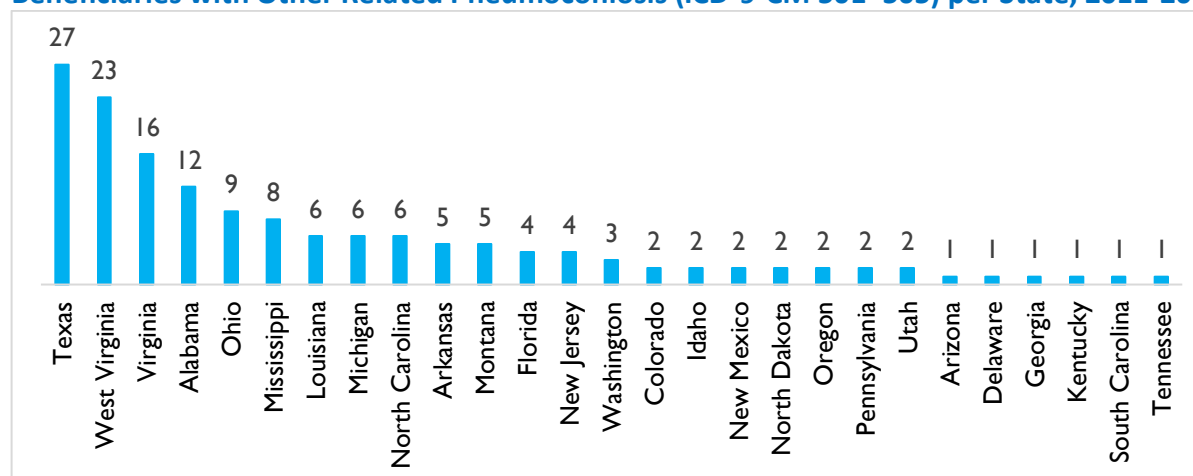
The spatial clustering analysis for rates of health care utilization for Medicare beneficiaries with Other Related Pneumoconiosis as the discharge diagnosis showed two distinctive cluster patterns (Figure 6). The first was a cluster of 38 counties in Appalachia (22 of these counties are in West Virginia). The second distinctive pattern comprised 25 counties with significantly higher health care utilization rates in eastern Texas and western Louisiana (Figure 6). Texas (n=27), West Virginia (n= 23), and Virginia (n=16) reported the largest number of counties with significantly high rates of health care utilization for Medicare beneficiaries with Other Related Pneumoconiosis as compared to other states in the country (Figure 7).

**Figure 6. Spatial Clustering Analysis of Four-Year Rate of Health Care Utilization for Medicare Beneficiaries with Other Related Pneumoconiosis (ICD-9-CM 501–505) as the Discharge Diagnosis, 2011-2014.**





**Figure 7. Number of Counties with Significantly High Rates of Health Care Utilization for Medicare Beneficiaries with Other Related Pneumoconiosis (ICD-9-CM 501–505) per State, 2011-2014.**



### Conclusions and Potential Policy Implications

The geographical patterns and spatial clustering analysis of health care utilization rates for Medicare beneficiaries with CWP from 2011 to 2014 show significantly elevated rates of health care utilization in counties in the central Appalachian states (West Virginia, Kentucky, and Virginia) as compared to other parts of the country. These findings signify the need for expanding access to health care for individuals with CWP, particularly in some counties in southern Illinois and western Kentucky. However, the significance of clusters of health care utilization rates among beneficiaries with Other Related Pneumoconiosis is unknown. Since CWP and other “dusty lung diseases” such as silicosis and asbestosis that are part of Other Related Pneumoconiosis can coexist, there is a need for further studies to understand the characteristics of these beneficiaries and the underlying disease etiology.

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**Interactive GIS maps, Supplementary Figures 1-4, may be viewed online at:**

<https://ruhrc.uky.edu/infographics>

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