Received Date:

Revised Date:

Accepted Date:

Article Type: Original Article

Geographic access to lung cancer screening among eligible adults living in rural and urban environments in the US

Running head – access to lung cancer screening

Key words – Lung cancer; access to screening; GIS; rural-urban

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"Funding,"

Part of the time for this work for Liora Sahar, Vanhvilai L. Douangchai Wills, and Liu, Ka Kit (Antonio), was funded by the National Lung Cancer Roundtable.

"Conflicts of Interest."

None, for Ella A. Kazerooni, Liora Sahar, Vanhvilai L. Douangchai Wills, and Liu, Ka Kit (Antonio)

Robert A. Smith and Stacey Fedewa are employed by the American Cancer Society, which receives grants from private and corporate foundations, including foundations associated with companies in the health sector, outside of the submitted work. Their salary is funded solely through American Cancer Society funds.

Lauren Rosenthal is employed by the American Cancer Society, which receives grants from private and corporate foundations, including foundations associated with companies in the health sector, outside of the submitted work. Her salary is partially funded by the National Lung Cancer Roundtable.

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Acknowledgment

This research was supported by the American College of Radiology's National Radiology Data Registry (NRDR). The authors wish to thank ACR staff for assistance in preparation of the data and acknowledge guidance and input by the steering committee for this analysis.

Precis – This study utilizes geospatial analysis to examine access to lung cancer screening at graduating distances nationwide, and across rural-urban settings. Approximately 5% of the eligible population do not have access to lung cancer screening facilities within 40-miles; however, different patterns of accessibility are observed at different distances, between regions, and rural-urban environments.

Lay summary: As annual lung cancer screening rates remain low, this study examines access to lung cancer screening nationwide and across rural and urban settings. We utilized GIS network analysis of census tract level population to estimate access at different distances including 10/20/40/50/100 miles, and aggregated results to counties. Approximately 5% of the eligible population do not have access to screening facilities within 40-miles; however, different patterns of accessibility are observed at different distances, between regions, and rural-urban environments. Across all distances and geographies, there is a larger percentage of the population in rural geographies with no access.

Abstract

Background: Although recommended lung cancer screening with low-dose computed tomography scanning (LDCT) reduces mortality among high-risk adults, annual screening rates remain low. This study complements a previous nationwide assessment of access to lung cancer screening within 40-miles by evaluating differences in accessibility across rural and urban settings for the population aged 50-80 and subset eligible population based on the 2021 USPSTF LDCT lung screening recommendations.

Methods: We calculated distances from population centers to screening facilities (ACR Lung Cancer Screening Registry) and estimated the number of individuals who have access within graduating distances including 10/20/40/50/100 miles. Census tract results were aggregated to counties, and both geographies were classified using rural-urban schemas.

Results: Approximately 5% of the eligible population do not have access to lung cancer screening facilities within 40-miles; however, different patterns of accessibility are observed at different distances, between regions, and rural-urban environments. Across all distances and geographies, there is a larger percentage of the population in rural geographies with no access. Although the rural population represents about 8% of the eligible population, the larger percentage of the rural population with no access is noteworthy and translates into larger number of individuals with no access at longer distance thresholds (>=40 miles).

Conclusion(s): Disparities in access should be examined as both percentages of the population and numbers of individuals with no access, to tailor interventions to communities and increase access. Geospatial analysis at the census tract level is recommended to help identify optimal focus areas and reach the most people.

1 Introduction

Lung cancer is a leading cause of cancer mortality in the United States,[1] and has one of the lowest 5-year survival rates due to the high proportion of late-stage diagnosis.[2] There are also higher lung cancer incidence and mortality rates in rural areas, probably due to higher smoking rates [3] and possibly more limited access to care.

Following the publication of results from the National Lung Screening Trial (NLST)[4], the United States Preventive Services Task Force (USPSTF) released recommendations in 2013 for annual lung cancer screening (LCS) for *"*adults aged 55 to 80 years who have a 30 pack-year smoking history and currently smoke or have quit within the past 15 years."[5] This was followed by private payor insurance coverage under the Affordable Care Act,[6] and coverage for Medicare beneficiaries by the Centers for Medicare and Medicaid Services (CMS)[6], and patients enrolled in Medicaid by most state-based Medicaid programs. As CMS required facilities to submit their data to a CMS-approved registry as a facility requirement for payment, the American College of Radiology (ACR) followed by creating the Lung Cancer Screening Registry (LCSR), the only CMS-approved registry.[7] In March 2021, the USPSTF released an update of their recommendation for LCS.[8] By both lowering the age at which screening begins to 50 and reducing the pack-year history criterion to 20, the population now eligible for LCS nearly doubled.

Recent reports still indicate very low annual screening by the eligible population[9,10] and variations of screening by state.[11] Adoption of any cancer screening program requires careful planning, assessment of risk and eligibility, and efforts to identify challenges and barriers including geographic access to screening facilities.[9,12] While several previous reports focused on geographic accessibility at the national and state levels,[13,14] this study expands upon a previous study, which reported results at the county level for the entire 55-79 (inclusive) population,[12] by focusing on the updated eligibility criteria of the 2021 USPSTF LCS recommendations and evaluating overall geographic access and differences in access between rural and urban areas.

2 Materials and Methods

Geospatial analysis is often used to calculate proximity, assess availability of health services, identify gaps in resources and inform public health policies.[12,15,16] We used Esri's ArcGIS® 10.6.1 for spatial analysis.

Data sources include lung cancer screening facilities, population, county smoking prevalence, percent of the eligible population by state, and rural-urban classifications at the county and census tract levels. A list of LCS facilities in the ACR LCSR (referred to as "facilities" for the rest of the text) was provided and verified by the organization in May 2020. They were geocoded using Esri's ArcGIS® World Geocoder to obtain their coordinates for mapping and analysis. Figure 1 shows the 3,249 unique geocoded facilities with greatest facility density in Florida (212), New York (203) and Pennsylvania (173).

Based on a recent evaluation of methodologies for estimating access,[12] we utilized road network analysis (preferred over the Euclidean distance method[16,17,18]) to calculate distances between population centers (represented by census tract centroids) and facilities. Population estimates for the age group 50-80 were downloaded from the US Census (2013-2018 American Community Survey 5-year Estimates).[19] The entire census tract population is considered as either having access or not having access within the distance from the centroid to the closest screening facility. Because each county consists of several census tracts, we calculated the percentage of the entire population aged 50-80 within the county that has access to a facility and categorize counties as having 'full access' (all census tracts within have access), 'partial access' (some census tracts have access) and 'no access'.

Multiple classifications of "rural" and "urban" exist. They differ in their spatial delimitation and their utilization for health policies and in cancer studies.[20,21,22] Different studies have evaluated aspects of disparities related to health in rural areas, including access to care and health outcomes.[20-26] While not consistently showing a clear rural-urban discrepancy and/or disparity, the definition of rural and its geographic delineation are important to identify specific challenges, barriers, local disparities, and focus areas for interventions. Limiting aggregation of the data, such as utilizing the census tract level definition of rurality, is preferred to better identify barriers to care and local focus areas.[20-22]

To evaluate accessibility across rural and urban environments in census tracts and counties, access was defined using multiple threshold distances of 10/20/40/50/100 miles. While realizing that 100 miles is not a common travel distance for screening services, we present the results to illustrate gaps and disparities in services. Because we report results at the census tract and county levels, we use rural-urban categories for both geographies. Counties were designated as rural, metro, or micro based on the Office of Management and Business's (OMB)[27] categories that are often used for policy for evaluating differences between counties. Census tracts were designated according to the consolidated rural-urban commuting area (cRUCA) scheme [20], a seven category consolidation of the USDA's RUCA[28] numbered from 1 representing "Urban Core" to 7 representing "Isolated rural" (Table 1). The "more urban" categories are numbered 1-4 and the "more rural" categories are numbered 5-7.

We estimated the number of the eligible population in each state and further in each county based on state level estimates of the percent of the eligible population according to the updated USPSTF recommendations[11] as follows:

- **Estimating the state eligible population (SEP):** We multiplied the recently published percentages of the estimated eligible population within the state[11] by the population aged 50-80 from the American Community Survey.[19]

- **Distributing the county eligible population (CEP):** In order to avoid uniform distribution of the eligible population across all counties, the calculated state eligible population was allocated across counties in the state relative to the number of the estimated individuals who smoke aged 50-80 years in the counties (using county smoking prevalence[29]).

$$CEP = \frac{CP_{50-80} * CSP}{\sum_{counties\ in\ the\ State}(CP_{50-80} * CSP)} * SEP$$

Equation 1- Calculating County estimated Eligible Population (CEP). CP = County population. CSP = County Smoking Prevalence

- **Estimating the eligible population with access:** We multiplied the eligible population in each county (as explained above) by the percent of the population with access at the county level.

Results are reported at different geographic levels to illustrate observed patterns and potential disparities of access to screening facilities nationwide and in rural-urban settings for all adults aged 50-80 and the subset eligible population.

3 Results

Approximately 15% of all adults aged 50-80 are eligible for LCS but this varies across states from 7.9% in Utah to 19.8% in Tennessee [11] Most of the eligible population (81.4%) lives within metropolitan counties, 10.6% live in micropolitan counties and 7.9% in rural counties (Table 1). We calculated the state eligible population (SEP) for each state and found that out of over 100.1M individuals aged 50-80 in the US, approximately14.8 million people aged 50-80 are eligible for LCS. Table 1 presents the numbers and percentages of the 50-80 population and the subset eligible population across rural-urban census tracts and counties and with no access within 10/20/40/50/100 miles of a facility, i.e., 86% of the population 50-80 in rural counties are not served by a facility within 10 miles, and 63% within 20 miles, 16% within 60 miles, and so on. As expected, Figure 2 shows more people have access as the distance to facilities increases, starting from almost 70% access at 10 miles to over 99% access at 100 miles. Consistent with the previous report,[12] approximately 5% of the population does not have access at 40 miles.

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Overall, 5.1% of the eligible population do not reside within 40 miles of a facility, and this proportion is markedly higher among individuals living in micropolitan and rural counties at 17.1% and 24.5%,

respectively. These percentages translate into 753,037 eligible people not having access to a facility, including 192,120; 270,115; and 287,803 people living in metro, micro, and rural counties, respectively.

While the number of individuals within census tracts or counties differs when calculating access for all people aged 50-80 (>100.1M) compared to the eligible population (>14.8M), both show very similar patterns of accessibility. Figure 3 reveals variability in access to LCS, and a noticeable trend of lower access in the west including the middle of the country compared to the east. Red and orange tracts (left column) indicate access in urban or close to urban areas, while the blue colors indicate access in small towns and in close-proximity to small towns. Gray indicates rural areas.

The maps showing access within 10 and 20 miles are predominantly red and indicate access of approximately 69% and 85%, respectively, mainly in urban areas, with the 10-mile map showing access in the larger cities across the nation and more predominately in the eastern states. At 40 and 50 miles, consistent with a previous report,[12] there is higher access in the eastern US with several pockets of low access in Southeast Maine, West Virginia, Georgia, Alabama, and Mississippi. Greater within-state variation in access is seen in sections of the middle states from North Dakota to Texas and the mountain states. Within 100 miles, there are still apparent areas with no access, mostly in the mountain states. This population represents <1% of the total 50-80 population, but accounts for over 600K estimated individuals 50-80 and fewer than 100K who are estimated to be eligible for LCS. Figure 3 shows similar patterns of access as the maps of the eligible population in the appendix.

We further examine the distribution of facilities and population across rural and urban designated counties (OMB's Metro/Micro/Rural designation) and census tracts (cRUCA). Eighty-eight percent of facilities (2,859) are located in more urban census tracts (cRUCA 1-4) where approximately 92% of the 50-80 population resides. Urban Core census tracts (cRUCA 1), whe 70.5% of the 50-80 population resides, have 2,331 or 72% of the facilities. About 84% of the 50-80 population resides in metro designated counties where there are 2,595 or 80% of facilities. In contrast, 298 or 9% of facilities, are located in rural designated counties where 6.7% of the 50-80 population resides, and 388 or 12% are in more rural census tracts (cRUCA 5-7) where less than 8% of that population resides. Out of 3,142 total counties, 1,707 (54%) do not have access to a facility (no access for all census tracts within the counties) within 10 miles, of which 1,026 (60%) are rural counties and 332 (19%) metro counties. At 100 miles, only 96 (3%) of counties do not have access to a facility, of which 77 (80%) are designated rural, and 3 (3%) metro. Figures 4 and 5 show the trend of the number and percent of individuals with no access to a facility across the distance thresholds, and across rural and urban categories, at the county and census tract levels (cRUCA 1-7). In Figure 4, Graphs A1 and B1 clearly show there are more individuals in metro counties who do not have access within 10 and 20-miles than non-metro counties, while numbers at distances

greater than 40 miles are very similar. Graphs A2 and B2 in Figure 4 show that a greater percentage of individuals residing in non-metro counties do not have access to screening across all the distances up to 100 miles. The graphs at the census tract level (A1 and B1 in Figure 5) show a change in the trend of the number of individuals with no access at 20 miles, where the number of individuals with no access within the isolated rural category (cRUCA 7) surpasses the number of individuals in the urban core category (cRUCA 1). Trends of census tracts in Figure 5 provide greater differentiation in trends across rural and urban categories compared to the aggregated county geographies. While the overall trends are similar, we can identify differences between the rural-urban census tract categories compared with the county trends. The trend line of the number of individuals with no access (Figure 4 A1, B1) in metro counties converges with the non-metro counties at 40 miles, but subtle trend changes are observed at 20 miles for some census tract categories. There is a consistently higher percentage of individuals with no access in the more rural geographies than the urban geographies. The anomaly of cRUCA 4 (Close Proximity to Urban Cluster) is attributed to changes that were made to the original RUCA codes in 2019.[28] A review of the revised census tract rural-urban classifications by the USDA shows a greater number of rural designated census tracts.[28] This trend is particularly pronounced by the red line in Graphs A2 and B2 in Figures 4 and 5, representing metro counties or urban core census tracts, respectively, that are below all the other categories up to 100 miles. For example, Table 1 shows that the percent of individuals with no access at 10 miles in rural counties (86%) is almost 4x higher than the percent in metro counties (22%). The relative gap increases at 100 miles, showing 3.4% in rural counties and only 0.2% in metro counties. Similar trends appear across census tracts where no access within 10 miles in isolated rural census tracts (90%) is over 7 times higher than urban core tracts (12%) and about 6 times higher in small town census tracts (78%). A similar trend is observed when determining access for the subset 50-80 estimated eligible population in the counties and census tracts.

Category		**Total & Eligible 50-80 Year Old Population (% eligible)**	**10 Miles - Number (%) with no access**	**20 Miles Number (%) with no access**	**40 Miles Number (%) with no access**	**50 Miles Number (%) with no access**	**100 Miles Number (%) with no access**
Total Nationwide							
Total Nationwide	Total 50-80	100,133,060	30,802,334 (30.8%)	14,631,228 (14.6%)	4,848,270 (4.8%)	3,041,998 (3.0%)	625,100 (0.6%)
	Eligible pop	14,816,638	4,870,365 (32.9%)	2,359,577 (15.9%)	753,037 (5.1%)	461,340 (3.1%)	87,145 (0.6%)
Counties							

Metropolitan	Total 50-80	84,218,801 (84.1%)	18,772,623 (22.3%)	6,283,304 (7.5%)	1,392,595 (1.7%)	761,743 (0.8%)	141,724 (0.2%)
	Eligible pop	12,063,206 (81.4%)	2,801,695 (23.2%)	941,538 (7.8%)	195,120 (1.6%)	103,534 (0.9%)	17,363 (0.1%)
Micropolitan	Total 50-80	9,212,196 (9.2%)	6,294,943 (68.3%)	4,106,720 (44.6)	1,723,447 (18.7%)	1,126,270 (12.2%)	255,024 (2.8%)
	Eligible pop	1,577,708 (10.6%)	1,063,644 (67.4%)	679,151 (43.0%)	270,115 (17.1%)	171,405 (10.9%)	36,278 (2.3%)
Rural	Total 50-80	6,702,063 (6.7%)	5,734,768 (85.6%)	4,241,204 (63.3%)	1,732,228 (25.8%)	1,153,985 (17.2%)	228,352 (3.4%)
	Eligible pop	1,175,724 (7.9%)	1,005,026 (85.5%)	738,889 (62.8%)	287,803 (24.5%)	186,401 (15.9%)	33,504 (2.8%)
Census Tracts							
cRUCA 1 - Urban core	Total 50-80	70,596,831 (70.5%)	8,761,855 (12.4%)	1,979,637 (2.8%)	571,916 (0.8%)	367,684 (0.5%)	79,296 (0.1%)
	Eligible pop	9,935,988 (67.1%)	1,235,550 (12.4%)	276,687 (2.8%)	78,741 (0.8%)	49,892 (0.5%)	9,535 (0.1%)
cRUCA 2 - Close proximity to urban core	Total 50-80	12,921,699 (12.9%)	9,816,833 (76.0%)	4,088,667 (31.6%)	718,519 (5.6%)	356,815 (2.8%)	51,828 (0.4%)
	Eligible pop	2,051,723 (13.8%)	1,573,685 (76.7%)	656,395 (32.0%)	110,532 (5.4%)	52,364 (2.6%)	6,689 (0.3%)
cRUCA 3 - Urban cluster	Total 50-80	8,726,387 (8.7%)	5,627,755 (64.5%)	3,707,250 (42.5%)	1,516,963 (17.4%)	966,653 (11.1%)	223,067 (2.6%)
	Eligible pop	1,487,785 (10.0%)	945,457 (63.5%)	612,035 (41.1%)	237,289 (15.9%)	147,806 (9.9%)	31,612 (2.1%)
cRUCA 4 - Close proximity to urban cluster	Total 50-80	206,645 (0.2%)	182,326 (88.2%)	139,618 (67.6%)	80,457 (38.9%)	62,471 (30.2%)	10,125 (4.9%)
	Eligible pop	33,662 (0.2%)	29,552 (87.8%)	22,353 (66.4%)	12,567 (37.3%)	9,735 (28.9%)	1,359 (4.0%)
cRUCA 5 - Small town	Total 50-80	4,217,583 (4.2%)	3,298,941 (78.2%)	2,418,874 (57.4%)	974,871 (23.1%)	606,428 (14.4%)	123,828 (2.9%)
	Eligible pop	728,066 (4.9%)	565,343 (77.6%)	411,215 (56.5%)	156,034 (21.4%)	92,878 (12.8%)	16,997 (2.3%)
cRUCA 6 - Close proximity to small town	Total 50-80	102,710 (0.1%)	88,090 (85.8%)	58,755 (57.2%)	25,375 (24.7%)	19,286 (18.8%)	7,656 (7.5%)
	Eligible pop	16,676 (0.1%)	14,354 (86.1%)	9,108 (54.6%)	3,718 (22.3%)	2,750 (16.5%)	967 (5.8%)
cRUCA 7 - Isolated rural area	Total 50-80	3,360,626 (3.4%)	3,026,534 (90.1%)	2,238,427 (66.6%)	960,169 (28.6%)	662,661 (19.7%)	129,300 (3.8%)
	Eligible pop	562,665 (3.8%)	506,422 (90.0%)	371,784 (66.1%)	154,155 (27.4%)	105,914 (18.8%)	19,987 (3.6%)

Table 1. Number and percentage of individuals aged 50-80 years and people eligible for screening without a screening facility at distances of up to 10/20/40/50/100 miles across rural and urban counties and census tracts. County data are aggregated from census tracts. Percent of people without access for each category was calculated by dividing the number of individuals without access by the total number of people 50-80 or eligible individuals within the category (the first column).

While most residents across all distances have access to a facility, there are differences in access among the rural-urban categories. The differences decrease as distances increase for both the numbers and percentages, however the higher distances themselves translate into a *de facto* lack of access if the distance is regarded as too great. For example, at 10 miles, 22% of residents in metro counties representing about 18.7M individuals aged 50-80 or an estimated 2.8M eligible individuals (12% in urban core census tracts) do not have access, compared to 86% of residents in rural counties representing about 5.7M individuals aged 50-80 or an estimated 1M eligible individuals (and up to 90% in rural census tracts). At 40 miles, most individuals across all categories have access to screening with more individuals having no access in rural counties compared to metro counties, but the difference is fewer than 400K people aged 50-80 and fewer than 100K eligible individuals. Those with no access at 40 miles, range from only 1.7% of residents of metro counties to 26% of rural counties and similarly 0.8% in urban core census tracts and 29% in rural census tracts. As distances increase, geographic barriers in access to screening impact a smaller percent of the 50-80 population showing about 5% of the population with no access at 40 miles and <1% at 100 miles. Those seemingly small percentages are translated into thousands of individuals and at 100 miles, almost 500k people aged 50-80 in non-metro counties and about 70k eligible individuals. Although a similar trend is apparent at the census tract and county levels, census tract level analysis can identify local, sub-county variations and potentially help to better focus on specific challenges in access and design interventions in communities.

4 Discussion

Overall, the distribution of facilities across rural and urban census tracts and counties is aligned with the distribution of adults eligible for LCS who reside in those areas, although some eligible adults will face long travel times (> 40 miles). As expected, the proportion of individuals in more rural areas with no or less access to LCS is higher across all distances compared with the metro and urban areas. Due to the distribution of the population and the higher population density in metro and urban areas, a higher proportion of people with no access in a category does not necessarily translate into a higher number of individuals. While the population in urban areas is concentrated in smaller geographic areas, rural areas

span larger geographies, have lower population density, and most of the areas with no access are in frontier regions west of the Mississippi River.

Disparities in lung cancer incidence and mortality in rural areas exist.[3] It is important to identify and address barriers and challenges and evaluate their impact on uptake of screening and poorer outcomes[30,31]. Such barriers also include lack of provider-patient communication about LCS, geographic access to screening[32], and lack of transportation.[33] To evaluate disparities across rural-urban environments and identify barriers to LCS, it is important to assess geographic access to screening at different distances and their impact in different communities. There are fewer facilities in rural areas, so residents need to travel longer distances to reach a facility. Our results show that a higher percentage of the population in rural counties and in less urban census tracts do not have access to facilities across all the distance thresholds. A pattern of geographic disparity in access is evident in the central and west as clusters of geographies (Figure 3) do not have access to facilities, creating large geographic areas with no access even at 50 miles and still apparent (but smaller) at 100 miles. Notable pockets of no access represent several rural counties and census tracts and should be identified and addressed. Specifically, local disparities can be better addressed at the census tract level because aggregation to counties tends to mask access as partial access (graduated color scheme in Figure 3) especially in the east. Geospatial analysis that integrates additional variables such as mortality rates and smoking rates may help identify focus areas for intervention to strategically reach the greatest number of people.

There are some limitations in this study. Our analysis focused on ACR LCSR facilities, which account for the majority of facilities offering LCS in the US. However, some health systems do not participate in the LCSR, such as the Department of Veterans Affairs, the Department of Defense operated health care facilities, the Indian Health Service, and capitated health care systems and facilities that provide service only to non-Medicare beneficiaries, all of which would result in an underestimate of access to screening. Administratively, some health care systems, that have multiple screening facilities, are entered into the ACR LCSR as one single entity, and may contribute to an underestimate of access to screening. There is no available public dataset to estimate pack-years of exposure at the county level to integrate into population eligibility. We distributed state level estimates of the eligible population[11] among counties in each state based on the relative number of people who smoked within counties, which may differ from the actual number of eligible individuals within each county. The number of people who currently smoke or once smoked is based on the reported percentage of adults (18+ years old) who have a history of cigarette smoking.[29] Additional limitations relate to the nature of the spatial analysis. We consider facilities within multiple distances from population centers regardless of political boundaries. We represented census tract populations using centroids for distance calculations. Generally, rural geographies span larger areas

compared to urban geographies, which introduce larger potential estimation errors. Additionally, we assume a similar capacity for all facilities and do not consider barriers to care such as financial, insurance coverage, cultural, or differences in transportation infrastructure that may vary greatly between rural and urban environments.

5 Conclusion

The nationwide distribution of lung cancer screening facilities has heterogeneity, with clear regional distinction between states in the east and central-west. Hierarchical evaluation of access across states, counties, and census tracts may be useful for decision making and informing interventions and policies at different levels and across rural and urban environments. We recommend calculating access using census tracts and then aggregating to other geographic levels to achieve a more accurate assessment of access. Across all distances in this analysis there is a significantly higher percentage of rural residents who do not have access to facilities compared to those in urban settings. However, the total number of individuals with no access in urban areas exceeds that of rural individuals, particularly at shorter distances, and should be considered as well because it reveals an additional underserved population. Different distance thresholds are essential for assessing geographic accessibility across rural and urban environments and may help in strategically identifying focus areas to better allocate resources across rural and urban areas. Areas and local pockets with persistently low or no access across short and long distances should be considered for tailored interventions such as implementing mobile units, re-purposing existing imaging or health facilities, and adding appropriate navigation, radiology and screening program staff to better support the communities. Additional research should focus on addressing unique barriers to LCS in rural and urban communities nationally and regionally to guide strategic implementation of programs that are appropriate to the type and geography of communities.

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Figure Legends

Figure 1. Lung cancer screening facilities participating in the LCSR. Blue dots indicate "Active" locations, which have submitted data to ACR and red dots indicate "Pending," locations, which are enrolled but have not yet submitted data to the registry

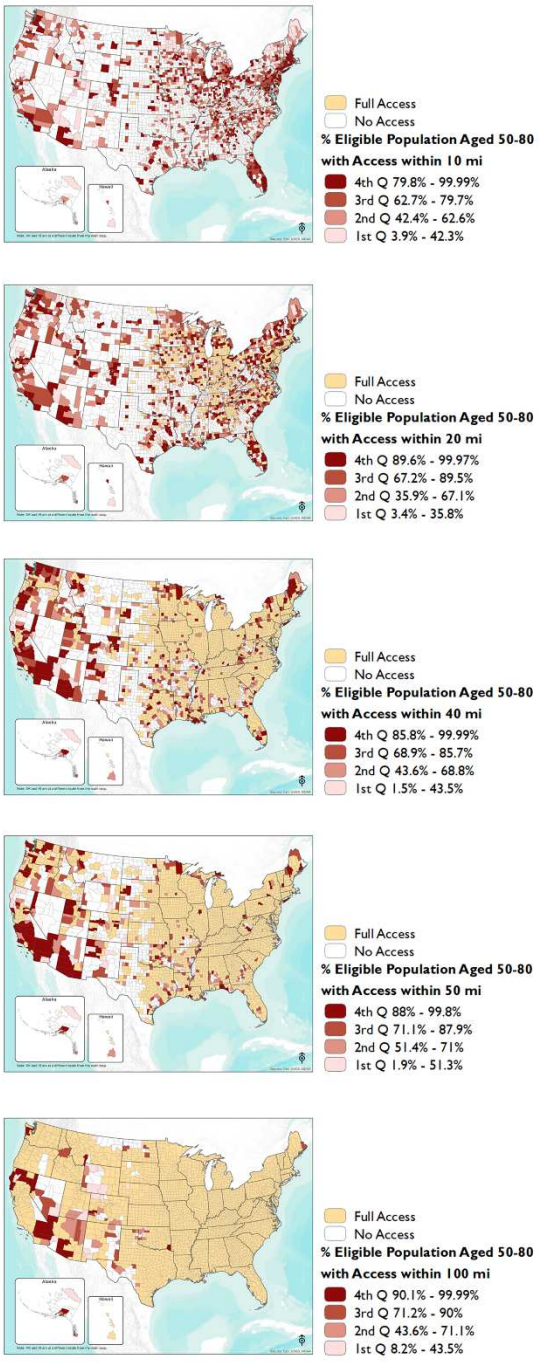
Figure 2. Accessibility of 50-80 (Top) and the eligible 50-80 (Bottom) as calculated across different distances. Blue indicates those who have access while orange is the part of the population that does not have access out of the ~100.1M total 50-80 population (Top) and out of the ~15M total eligible 50-80 population (Bottom).

Figure 3. Access to lung cancer screening calculated using census tracts and counties. Maps indicate access at progressively longer distances beginning at10 miles at the top through 100 miles at the bottom. No access is represented in white. Maps on the left show access at the census tract level where census tracts with access are colored according to their cRUCA designation. Maps of access at the county level are shown on the right using darker graduating colors indicating increase in access and hatches and dots depict full access. Maps were evaluated for common color blindness using the Color Oracle tool available at https://colororacle.org/design.html.

Figure 4. Number and percent of individuals without access to a LCSR facility across metro/micro/rural counties. Graph lines show the decreasing trend of no access across 10/20/40/50/100 miles as more people have access as the distance threshold increases. The top "A" images refer to all individuals 50-80 while the bottom "B" images refer to the eligible individuals ages 50-80 within the county. Percent values refer to the proportion of individuals within that category who do not have access (for example, the gray dotted line in A2 refers to the percent of individuals in rural counties who do not have access out of all the population 50-80 residing in rural counties while the gray dotted line in B2 refers to the percent of eligible individuals in rural counties who do not have access out of all the eligible population 50-80 residing in rural counties.

Figure 5. Number and percent of individuals without access to a screening facility across cRUCA census tract designations. Graph lines show the decreasing trend of no access across 10/20/40/50/100 miles as more people have access as the distance threshold increases. Top "A" images refer to all individuals 50-80 while the bottom "B" images refer to the eligible individuals within the county. Percent values refer to the proportion of individuals within that category who do not have access (for example, the gray dotted line in A2 refers to the percent of individuals in rural census tracts who do not have access out of all the population 50-80 residing in rural census tracts while the gray dotted line in B2 refers to the percent of eligible individuals in rural census tracts who do not have access out of all the eligible population 50-80 residing in rural census tracts.

7 Appendix.



Appendix Figure: Access to lung cancer screening depicting percent of the eligible population with access. Maps indicate access at progressively longer distances beginning at 10 miles at the top through 100 miles at the bottom using graduating colors (by quartiles). No access is represented in white and full access in yellow.

Category		Total & Eligible 50-80 Year Old Population (% eligible)	10 Miles - Number (%) with no access	20 Miles Number (%) with no access	40 Miles Number (%) with no access	50 Miles Number (%) with no access	100 Miles Number (%) with no access
Total Nationwide							
Total Nationwide	Total 50-80	100,133,060	30,802,334 (30.8%)	14,631,228 (14.6%)	4,848,270 (4.8%)	3,041,998 (3.0%)	625,100 (0.6%)
	Eligible pop	14,816,638	4,870,365 (32.9%)	2,359,577 (15.9%)	753,037 (5.1%)	461,340 (3.1%)	87,145 (0.6%)
Counties							
Metropolitan	Total 50-80	84,218,801 (84.1%)	18,772,623 (22.3%)	6,283,304 (7.5%)	1,392,595 (1.7%)	761,743 (0.8%)	141,724 (0.2%)
	Eligible pop	12,063,206 (81.4%)	2,801,695 (23.2%)	941,538 (7.8%)	195,120 (1.6%)	103,534 (0.9%)	17,363 (0.1%)
Micropolitan	Total 50-80	9,212,196 (9.2%)	6,294,943 (68.3%)	4,106,720 (44.6)	1,723,447 (18.7%)	1,126,270 (12.2%)	255,024 (2.8%)
	Eligible pop	1,577,708 (10.6%)	1,063,644 (67.4%)	679,151 (43.0%)	270,115 (17.1%)	171,405 (10.9%)	36,278 (2.3%)
Rural	Total 50-80	6,702,063 (6.7%)	5,734,768 (85.6%)	4,241,204 (63.3%)	1,732,228 (25.8%)	1,153,985 (17.2%)	228,352 (3.4%)
	Eligible pop	1,175,724 (7.9%)	1,005,026 (85.5%)	738,889 (62.8%)	287,803 (24.5%)	186,401 (15.9%)	33,504 (2.8%)
Census Tracts							
cRUCA 1 - Urban core	Total 50-80	70,596,831 (70.5%)	8,761,855 (12.4%)	1,979,637 (2.8%)	571,916 (0.8%)	367,684 (0.5%)	79,296 (0.1%)
	Eligible pop	9,935,988 (67.1%)	1,235,550 (12.4%)	276,687 (2.8%)	78,741 (0.8%)	49,892 (0.5%)	9,535 (0.1%)
cRUCA 2 - Close proximity to urban core	Total 50-80	12,921,699 (12.9%)	9,816,833 (76.0%)	4,088,667 (31.6%)	718,519 (5.6%)	356,815 (2.8%)	51,828 (0.4%)
	Eligible pop	2,051,723 (13.8%)	1,573,685 (76.7%)	656,395 (32.0%)	110,532 (5.4%)	52,364 (2.6%)	6,689 (0.3%)
cRUCA 3 - Urban cluster	Total 50-80	8,726,387 (8.7%)	5,627,755 (64.5%)	3,707,250 (42.5%)	1,516,963 (17.4%)	966,653 (11.1%)	223,067 (2.6%)
	Eligible pop	1,487,785 (10.0%)	945,457 (63.5%)	612,035 (41.1%)	237,289 (15.9%)	147,806 (9.9%)	31,612 (2.1%)
cRUCA 4 - Close proximity to urban cluster	Total 50-80	206,645 (0.2%)	182,326 (88.2%)	139,618 (67.6%)	80,457 (38.9%)	62,471 (30.2%)	10,125 (4.9%)
	Eligible pop	33,662 (0.2%)	29,552 (87.8%)	22,353 (66.4%)	12,567 (37.3%)	9,735 (28.9%)	1,359 (4.0%)
cRUCA 5 - Small town	Total 50-80	4,217,583 (4.2%)	3,298,941 (78.2%)	2,418,874 (57.4%)	974,871 (23.1%)	606,428 (14.4%)	123,828 (2.9%)

	Eligible pop	728,066 (4.9%)	565,343 (77.6%)	411,215 (56.5%)	156,034 (21.4%)	92,878 (12.8%)	16,997 (2.3%)
cRUCA 6 - Close proximity to small town	Total 50-80	102,710 (0.1%)	88,090 (85.8%)	58,755 (57.2%)	25,375 (24.7%)	19,286 (18.8%)	7,656 (7.5%)
	Eligible pop	16,676 (0.1%)	14,354 (86.1%)	9,108 (54.6%)	3,718 (22.3%)	2,750 (16.5%)	967 (5.8%)
cRUCA 7 - Isolated rural area	Total 50-80	3,360,626 (3.4%)	3,026,534 (90.1%)	2,238,427 (66.6%)	960,169 (28.6%)	662,661 (19.7%)	129,300 (3.8%)
	Eligible pop	562,665 (3.8%)	506,422 (90.0%)	371,784 (66.1%)	154,155 (27.4%)	105,914 (18.8%)	19,987 (3.6%)

Table 1. Number and percentage of individuals aged 50-80 years and people eligible for screening without a screening facility at distances of up to 10/20/40/50/100 miles across rural and urban counties and census tracts. County data are aggregated from census tracts. Percent of people without access for each category was calculated by dividing the number of individuals without access by the total number of people 50-80 or eligible individuals within the category (the first column).