ORIGINAL ARTICLE

Lung Cancer Screening Eligibility and Use: A Population Health Perspective of One Community

Tina D. Tailor, Norma E. Farrow, Junheng Gao, Kingshuk R. Choudhury, Betty C. Tong

BACKGROUND Low-dose chest CT (LDCT) is the only effective screening test for lung cancer. Annual lung cancer screening (LCS) is recommended by the US Preventive Services Task Force (USPSTF) for individuals at high risk for primary lung neoplasm.

METHODS We retrospectively identified patients receiving LCS from January 2016 through March 2018 whose residential addresses were within our health center's county. We estimated driving distance from the patient's address to our health center and obtained sociodemographic characteristics from the electronic health record (EHR). The census-tract-level LCS-eligible population size was estimated, and their population characteristics determined via US Census Bureau, Centers for Disease Control and Prevention (CDC), and Behavioral Risk Factor Surveillance System (BRFSS) data. The Cochran-Mantel-Haenszel test was used to determine differences amongst the LCS-eligible and LCS-enrolled populations. Multivariable regression was used to determine the effects of sociodemographic characteristics on LCS eligibility.

RESULTS There was modest correlation between census-tract-level LCS-eligible population size and LCS enrollment (r = 0.68, P < .001). 5.9% (364/6185) of the estimated LCS-eligible population in our county received LCS, with census-tract LCS rates ranging from 1.5% to 12.5%. Nonwhite race status (Hispanic and African American) was associated with decreased likelihood of LCS enrollment compared to White race (OR = 95% CI, 0.765 [0.61, 0.95] and 0.031 [0.008, 0.124], respectively). Older age, Medicaid, and uninsured statuses were positively correlated with LCS eligibility ($P \leq .01$).

LIMITATIONS This analysis comprises a single county. Other LCS facilities within our health system in neighboring counties, as well as individuals receiving LCS outside of our health system, are not captured.

CONCLUSIONS The uptake of LCS remains low, with disproportionately lower screening rates amongst Hispanic and African American populations. Medicaid and uninsured patients in our community are also more likely to be LCS-eligible. These populations may be targets for interventions aimed at increasing LCS awareness and uptake.

Lung cancer is the leading cause of cancer mortality worldwide, causing over 140,000 annual deaths in the United States. [1]. While localized early disease is potentially curable, the high mortality rate is largely due to patients presenting at advanced disease stage. In 2011, the National Lung Screening Trial (NLST) demonstrated that annual lung cancer screening (LCS) with low-dose computed tomography (LDCT) reduced lung-cancer-specific mortality by approximately 20% and overall mortality by 6.7% in patients at high risk for developing lung cancer [2]. Subsequently, LCS guidelines were put forth by many national organizations, including the US Preventive Services Task Force (USPSTF) and the National Comprehensive Cancer Network (NCCN) [3, 4]. The Affordable Care Act mandates coverage for LCS with LDCT in privately insured, qualifying patients, and the 2015 Centers for Medicare and Medicaid Services (CMS) LCS coverage decision offers LDCT for LCS as a preventive health benefit to screen-eligible Medicare beneficiaries [3, 5]. Despite these national recommendations and insurance coverage decisions, LCS remains vastly underutilized, with estimates as low as 2.0% of screen-eligible patients undergoing screening in the year following the issuance of the 2015 USPSTF LCS recommendations [6].

The low rate of LCS utilization calls for an improved understanding of the barriers to LCS implementation and utilization [7–11]. The need to understand these barriers is compounded by sociodemographic disparities in cigarette smoking, lung cancer incidence, and lung cancer survival, which carry a greater burden for African Americans and populations of lower educational attainment and lower socioeconomic resources [11–15]. In this regard, a granular understanding of access and utilization of LCS may inform initiatives to improve uptake in vulnerable populations, aid in health system resource allocation, and potentially mitigate access barriers to screening [16].

The purpose of this study was to evaluate the utilization of LCS, at a census tract level, in Durham County, North Carolina. We specifically aimed to estimate the LCS-eligible population and LCS rate, compare sociodemographic characteristics between the LCS-eligible and LCS-enrolled populations, and investigate local population characteristics associated with LCS eligibility. Duke University Medical

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Address correspondence to Betty C. Tong, Duke University Medical Center 3531, Durham, NC 27710 (betty.tong@duke.edu).

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Center is the sole health center in Durham County and serves the majority of the county's residents, and this setting provides a unique opportunity to study LCS utilization at a local level [17]. This study may inform targeted community and/or health center priorities to promote equitable and appropriate LCS dissemination.

Methods

Data Sources

This HIPAA-compliant retrospective study utilized data from Duke University Medical Center's EHR and publicly available data sources. This study was approved by the Duke Institutional Review Board. We identified all patients who received a baseline LDCT for LCS from January 2016 through March 2018 at Duke University Medical Center. Patients with residential addresses outside of Durham County were excluded from analysis. Patient sociodemographic characteristics, including age, gender, race/ethnicity, home address, and insurance/payer, were collected from the EHR. Census tract shape files, population size, and population characteristics were obtained from the US Census Bureau (American Community Survey 5-year estimates, 2012–2016) for all census tracts in Durham County, North Carolina [18]. Census-tract-level smoking prevalence estimates for Durham County, North Carolina, were obtained from the CDC 500 Cities Project and previously published estimates (data estimates for year 2014) [19, 20]. BRFSS-derived state-level cigarette smoking frequency data were obtained from the CDC's State Tobacco Activities Tracking and Evaluation System (data estimates from year 2015) [21]. In addition, 2018 BRFSS-derived state-specific data on former smokers in the state of North Carolina were obtained from the North Carolina State Center for Health Statistics [22].

Estimations

Estimation of the LCS-eligible population size within each census tract was guided by the 2015 USPSTF criteria [3]. The 2015 USPSTF LCS recommendations define an LCS-eligible individual as one aged between 55 and 80 years with a 30 pack-year smoking history (e.g., equivalent of 1 pack per day for 30 years or 2 packs per day for 15 years), including current smokers or former smokers quitting within 15 years. The US Census Bureau reports census tract populations at 5-year intervals from 55 to 79 years, and therefore 79 years was selected as the upper age limit for the purposes of estimation. LCS-eligible current smokers per census tract were estimated by: (census tract population 55–79 years) × (census tract smoking prevalence) x (percent of daily smokers amongst current smokers) × (percent of daily smokers ≥ 15 cigarettes per day). LCS-eligible former smokers per census tract were estimated by: (census tract population 55–79 years) × (percent former smokers) × (age-adjusted percent former smokers quitting within 10 years). The LCS-eligible current and former smokers were summed to determine the total number of LCS-eligible individuals in each tract.

Driving distance between the patient's home address and our medical center was processed and calculated using Google Maps Application Program Interface [23].

Statistical Analysis and Data Visualization

Statistical analyses and data visualizations were conducted in R 3.4.1 (version 4.3.1, www.r-project.org). Census tract level choropleth maps, utilizing shape files from the US Census Bureau, were used to visualize LCS-eligible and enrolled population sizes. The Cochran-Mantel-Haenszel test was used to determine differences in population characteristics between the LCS-enrolled and estimated LCS-eligible populations, stratifying by census tract. Pearson's correlation was used to evaluate the association between census-tract-level LCS-eligible and LCS-enrolled population sizes. A multivariate Poisson model was used to determine the relationship between population-adjusted LCS-eligible persons per census tract and census tract sociodemographic characteristics. Coefficients from this Poisson model were standardized to a mean of 0 and a standard deviation (SD) of 1 to assess their relative strength in the model. All multivariate models assessed and addressed for multicollinearity and model diagnostics were performed to assess model fit. A P-value of < .05 was considered statistically significant.

Results

A total of 6185 individuals were estimated to be eligible for LCS in Durham County. Of these individuals, 364 (5.9%) received a screening examination (Table 1). Census-tract-level visualization revealed geospatial heterogeneity amongst LCS-eligible and enrolled populations (Figures 1a-1b); LCS rates (LCS-enrolled/LCS-eligible) ranged from 1.5% to 12.5% across the county (Figure 1c). There was an overall modest positive correlation between the census-tract-level LCS-eligible and enrolled population size ($r = 0.68$, $P < .001$), suggesting that screening is generally capturing at-need populations.

There were no statistically significant differences in gender and smoking status (current smoker versus former smoker) between the LCS-eligible and LCS-enrolled populations. Calculation of census tract level driving distance revealed that the population enrolled in LCS was located further from our medical center than the population estimated to be LCS-eligible (median distance 6.5 miles versus 4.7 miles, respectively, $P = .002$, Table 1). African American and Hispanic race statuses were associated with a significantly decreased likelihood of LCS enrollment compared to White race: African American versus White, OR = 0.765 (0.6141, 0.953); Hispanic versus White, OR = 0.031 (0.008, 0.124) (Table 1). Regarding insurance coverage for the population enrolled in LCS, most were Medicare beneficiaries (63.2%, 230/364), whereas commercial/private insurance and Medicaid coverage were observed with relatively less frequency [32.1% (117/364) and 4.4% (16/364)].

TABLE 1.
Population Characteristics of the LCS-Eligible and LCS-Enrolled Populations in Durham County

	LCS-Eligible Population (N = 6185)	LCS-Enrolled Population (n = 364)	% LCS-Eligible who are LCS Enrolled	*P*-Value	OR (95% CI) of LCS Enrollment amongst LCS-Eligibility
Total	6185	364	5.9%		
Gender				**.324**	
Male (ref)	2987 (48.3%)	184 (50.5%)	6.2%		
Female	3198 (51.7%)	180 (49.5%)	5.6%		0.914 (0.740,1.129)
Race				.001	
White (ref)	2711 (43.8%)	220 (60.4%)	8.1%		
African American	2222 (35.9%)	138 (38.0%)	6.2%		0.765 (0.614, 0.954)
Hispanic	803 (13.0%)	2 (0.6%)	0.25%		0.031 (0.008, 0.124)
Smoking Status				.882	
Current smoker (ref)	3478 (56.2%)	209 (58.1%)	6.0%		
Former smoker	2707 (43.8%)	149 (41.4%)	5.5%		0.916 (0.738, 1.137)
Median Age (years)	-	65 (61,70)	-	-	-
Distance to LCS center (miles)	4.7 (3.0, 5.9)	6.5 (4.3, 9.5)	-	.002	-

Note. The LCS-eligible population was estimated at the census tract level and aggregated here at the county level. The LCS-enrolled population was determined at the census tract level from our institution's EHR. Odds ratios (OR) and associated 95% confidence intervals (CI) are in reference to the values marked "ref."

A multivariate model was constructed to examine sociodemographic characteristics associated with LCS eligibility (Table 2). Census tracts with higher median age, as well those with larger Medicaid and uninsured populations, had a significantly higher LCS-eligible population (Table 2). Census tracts with a larger female population exhibited significantly lower LCS-eligible populations (Table 2).

Discussion

This is a detailed small-areas examination of variation in eligibility and enrollment in LCS in our county. We demonstrate that while LCS enrollment rates are modestly correlated with the at-need population (r = 0.68 between LCS-eligible and LCS-enrolled populations, $P < .001$), less than 6% of the LCS-eligible population in our county is enrolled in LCS. The low uptake of LCS in our population is congruent with reported national trends [6, 24]. By examining LCS uptake at the census tract level, we can identify local geographic variation in utilization (Figure 1). In light of the low utilization of LCS despite USPSTF recommendations and federal initiatives, it is likely that informed local, state, and community-level initiatives will be necessary to promote LCS in quantities sufficient to reduce lung cancer mortality. In this regard, analyses of LCS utilization, as performed here, may be integral toward informing this goal.

Census tract analysis revealed that patients enrolled in LCS live further from our health center than the estimated LCS-eligible population (Table 1). Although this difference is small (less than 2 miles), this result suggests that proximity to a screening facility may not necessarily predict

FIGURE 1.
Choropleth Maps at the Census Tract Level Showing the (a) Estimated LCS-Eligible Population, (b) LCS-Enrolled Population, and (c) Percentage of LCS-Eligible Who Are Enrolled in LCS

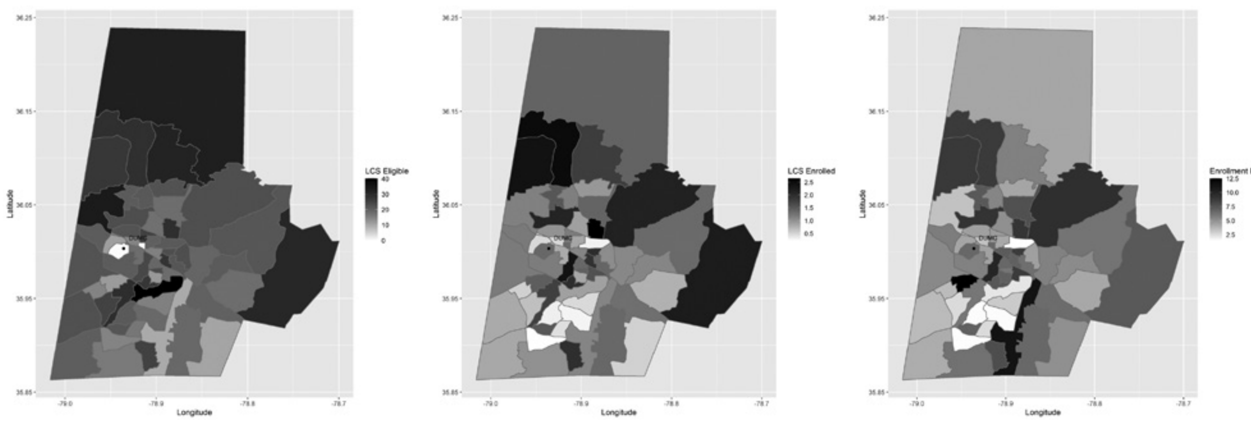

Figure 1a: LCS-Eligible Population (per 1000 persons)

Figure 1b: LCS-Enrolled Population (per 1000 persons)

Figure 1c: % of LCS-Eligible Population Enrolled in LCS

TABLE 2.
Multivariate Model Describing Census-Tract-Level Characteristics Associated With LCS Eligibility

Census tract characteristic	Coefficient	Standard Error	*P*-value	OR (95% CI)
Distance to DUMC (miles)	0.00030	0.016	.985	1.000 (0.970, 1.032)
% Female	-0.034	0.016	.038[a]	0.967 (0.937, 0.998)
% Nonwhite	0.023	0.028	.402	1.023 (0.970, 1.080)
Median Age	0.30	0.021	<.001[a]	1.344 (1.291, 1.400)
% With < high school degree	-0.050	0.044	.258	0.952 (0.873, 1.037)
Median Income	-0.036	0.032	.261	0.965 (0.906, 1.027)
% Adults uninsured	0.098	0.038	.011[a]	1.102 (1.023, 1.188)
% Medicare	0.031	0.016	.052	1.031 (1.000, 1.064)
% Medicaid	0.081	0.026	.002[a]	1.084 (1.030, 1.141)

[a]A multivariate Poisson model was used to determine the relationship between the census tract level LCS-eligible population and census-tract-level sociodemographic characteristics. Model coefficients were normalized to assess their relative strength on the dependent variable. Given ORs reflect the change in census tract LCS-eligible population/1000 persons for a 1 SD increase in the predictor variable.

use. Corroborating this observation, driving distance to our screening facility was not associated with LCS enrollment (Table 2). While prior work suggests a relative sparsity of LCS facilities in rural locations, prior estimates have also shown that the vast majority of adult smokers in the United States (> 80%) live within 15 miles of an American College of Radiology (ACR)-accredited CT facility [16, 25, 26]. Hence, lack of geographic access to a screening facility may not account for the low rate of LCS uptake amongst the majority of screen-eligible patients.

There were racial differences in LCS uptake, with African American and Hispanic patients being underrepresented in the LCS program relative to White individuals (Table 1). This supports other literature suggesting that White patients are more likely to be screened than nonwhite patients [27, 28]. Reasons for the underrepresentation of African Americans in LCS are unclear and warrant future study; these reasons are likely multifactorial. While the African American Health Engagement Study demonstrated that 88% of participants agree that "regular screenings are important," factors such as lack of physician referral, mistrust of providers, and inadequate access to health care may be barriers to LCS for some populations [28, 29]. Also likely contributory are racial/ethnic differences in tobacco use behaviors. Namely, prior work has shown that African Americans are less likely to meet the former 2015 USPSTF-required 30 pack-year smoking history LCS eligibility criterion than White patients [30, 31]. Despite lower pack-years of smoking, however, African Americans experience higher mortality from lung cancer than Whites and other racial groups [32]. It is therefore incumbent that screening appropriately capture high-risk African American patients. Importantly, while the NLST demonstrated that all screen-eligible racial groups experience mortality reduction with LCS, African Americans experience a significantly higher mortality benefit compared to White patients [2]. To this end, the recently updated 2021 USPSTF LCS recommendations, which lower the age and smoking pack-year thresholds for LCS eligibility to 50 years of age and 20 pack-years, respectively, may offer advantage in ensuring more robust capture of all individuals who are at risk for lung cancer [33].

Disparities in lung cancer outcomes for Hispanic populations have also been described. While stage-for-stage survival in Hispanic/Latino patients is equivalent or better when compared to non-Hispanic patients, Hispanic/Latino patients are more often diagnosed at later stages compared to non-Hispanic populations [34, 35]. Amongst other factors, the underrepresentation of Hispanic/Latino patients in our program may be partly due to lack of awareness. A recent study published by Percac-Lima and coauthors reported that less than half of Latinos surveyed were aware of screening tests for lung cancer detection [36]. However, when informed about LDCT and asked about their level of interest in LCS, more Latinos than non-Latinos were willing and interested in screening [35]. Efforts are ongoing at a national level to increase LCS awareness. In November 2018, the American Cancer Society's "Saved by the Scan" campaign launched Spanish-language messaging to increase LCS awareness among Hispanic populations [37].

Our results also suggest that census tracts with higher uninsured and Medicaid populations have higher populations of LCS-eligible individuals. This finding is in concordance with the higher rates of smoking in these sociodemographic populations [38]. Given the historically lower rates of screening exam utilization in these populations, as well as recent literature supporting that LCS may be predominantly enrolling patients with high socioeconomic status, it is likely that focused efforts will be needed to reach and include vulnerable populations with insurance challenges [39]. Failure to do so may, in the long term, perpetuate lung cancer survival disparities.

Limitations

There are limitations to this study. First, this analysis comprises a single county. As our health center is the only in-county health center (not including the VA), and the majority of the county's residents obtain health care at our center, this analysis provides a unique opportunity to estimate LCS enrollment amongst the estimated LCS-eligible population [17]. An estimated 60% of the county's population receives care at our medical center, and our medical center was the only ACR-designated LCS Center within our county during the time of this study. Importantly, however, the service area for our health system spans several regional counties and also draws patients from neighboring states and nationwide who are not captured here. There are also other LCS facilities within our health system that are in neighboring counties, which are not captured in this study. It is therefore possible that the uptake of screening amongst our county's population is underestimated, as patients may go outside of this health center to obtain LCS. We are also limited by the availability of data. The upper age limit in our estimated LCS-eligible cohort was 79 years; this does not exactly align with the USPSTF upper age limit of 80. However, since approximately 96% of patients in that age range have at least some Medicare coverage, where age > 78 would make them ineligible for LCS by Medicare criteria, our estimation of screen-eligible adults in Durham County is reasonable [40].

Conclusions

This work has demonstrated a detailed analysis and estimation of LCS enrollment at the census tract level. We have identified potential sociodemographic disparities in screening uptake. These patient populations may be targets for future interventions aimed at increasing LCS awareness and enrollment. NCMJ

Tina D. Tailor, MD assistant professor, Department of Radiology, Duke University Medical Center, Durham, North Carolina.
Norma E. Farrow, MD general surgery resident, Department of Surgery, Duke University Medical Center, Durham, North Carolina.
Junheng Gao, MS biostatistician, Department of Biostatistics and Bioinformatics, Duke Cancer Institute, Duke University Medical Center, Durham, North Carolina.
Kingshuk R. Choudhury, PhD adjunct associate professor, Department of Biostatistics and Bioinformatics, Duke University Medical Center, Durham, North Carolina.
Betty C. Tong, MD, MHS, MS associate professor of surgery, Department of Surgery, Division of Thoracic and Cardiovascular Surgery, Duke University Medical Center, Durham, North Carolina.

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