ORIGINAL RESEARCH

Racial Disparities in Adherence to Annual Lung Cancer Screening and Recommended Follow-Up Care

A Multicenter Cohort Study

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Abstract

Rationale: Black patients receive recommended lung cancer screening (LCS) follow-up care less frequently than White patients, but it is unknown if this racial disparity persists across both decentralized and centralized LCS programs.

Objectives: To determine adherence to American College of Radiology Lung Imaging Reporting and Data System (Lung-RADS) recommendations among individuals undergoing LCS at either decentralized or centralized programs and to evaluate the association of race with LCS adherence.

Methods: We performed a multicenter retrospective cohort study of patients receiving LCS at five heterogeneous U.S. healthcare systems. We calculated adherence to annual LCS among patients with a negative baseline screen (Lung-RADS 1 or 2) and recommended follow-up care among those with a positive baseline screen (Lung-RADS 3, 4A, 4B, or 4X) stratified by type of LCS program and evaluated the association between race and adherence using multivariable modified Poisson regression.

Results: Of the 6,134 total individuals receiving LCS, 5,142 (83.8%) had negative baseline screens, and 992 (16.2%) had positive baseline screens. Adherence to both annual LCS (34.8% vs. 76.1%; $P < 0.001$) and recommended follow-up care (63.9% vs. 74.6%; $P < 0.001$) was lower at decentralized compared with centralized programs. Among individuals with negative baseline screens, a racial disparity in adherence was observed only at decentralized screening programs (interaction term, $P < 0.001$). At decentralized programs, Black race was associated with 27% reduced adherence to annual LCS (adjusted relative risk [aRR], 0.73; 95% confidence interval [CI], 0.63–0.84), whereas at centralized programs, no effect by race was observed (aRR, 0.98; 95% CI, 0.91–1.05). In contrast, among those with positive baseline screens, there was no significant difference by race for adherence to recommended follow-up care by type of LCS program (decentralized aRR, 0.95; 95% CI, 0.81–1.11; centralized aRR, 0.81; 95% CI, 0.71–0.93; interaction term, $P = 0.176$).

Conclusions: In this large multicenter study of individuals screened for lung cancer, adherence to both annual LCS and recommended follow-up care was greater at centralized screening programs. Black patients were less likely to receive annual LCS than White patients at decentralized compared with centralized LCS programs. Our results highlight the need for further study of healthcare system–level mechanisms to optimize longitudinal LCS care.

Keywords: early detection of cancer; guideline adherence; healthcare disparities

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Lung cancer screening (LCS) with low-dose computed tomography (LDCT) reduced lung cancer mortality in two large randomized clinical trials, the NLST (National Lung Screening Trial) and the NELSON (Dutch-Belgian Randomized Lung Cancer Screening Trial) (1, 2). Since 2013, the U.S. Preventative Services Task Force has recommended annual LCS among high-risk adults with a history of smoking (3), and both public and private health insurances cover LDCT for LCS (4). To standardize LDCT interpretation and subsequent management recommendations, the American College of Radiology introduced the Lung Imaging Reporting and Data System (Lung-RADS) in April 2014, which has been shown to decrease the false-positive rate for diagnosing malignancy and is consistent with the current U.S. Centers for Medicare and Medicaid Services (CMS) reporting requirement (5–8). Per these recommendations, negative screens (Lung-RADS 1 or 2) warrant continued annual LCS, and positive screens (Lung-RADS 3 or 4) require more immediate follow-up, as risk of malignancy increases (5, 9).

As LCS with LDCT reduces lung cancer mortality by detecting earlier-stage cancers (1, 2, 10), adherence to Lung-RADS recommendations after an initial LDCT is critical and has been recommended as a quality metric for LCS programs (11). Among screen-detected lung cancers in the NLST and NELSON trials, 58% and 72% were diagnosed after the baseline screening period, respectively (1, 2). A recent study demonstrated that among high-risk individuals with a negative initial LDCT and no subsequent follow-up for at least 5 years, 21% were ultimately diagnosed with lung cancer (12). Although adherence to annual LCS was as high as 95% in clinical trials (1, 2), existing clinical practice data have demonstrated a significantly lower rate of real-world adherence (13, 14). Several prior studies have assessed factors associated with adherence (15–28). Centralized LCS programs with trained navigators have consistently been associated with increased adherence (17, 20, 21, 23, 26, 29) and, independently, Black race with reduced adherence (17, 20, 23, 30); however, to date no study has examined the effect of program centralization on adherence by race.

To address this knowledge gap, here we report the association between patient race and adherence to both annual LCS and recommended follow-up stratified by type of LCS program among individuals screened for lung cancer with LDCT across five heterogeneous U.S. healthcare systems. Some of the results of this study have been previously reported in the form of abstracts (31, 32).

Methods

Study Design and Population

We conducted a multicenter retrospective cohort study of adults screened for lung cancer at healthcare systems within the PROSPR (Population-based Research to Optimize the Screening Process)-Lung Consortium. PROSPR-Lung comprises five diverse, community-based healthcare systems across the United States: Henry Ford Health System (HFHS), Kaiser Permanente Colorado (KPCO), Kaiser Permanente Hawaii (KPHI), Marshfield Clinic Health System (MCHS), and University of Pennsylvania Health System (UPHS) (33). PROSPR-Lung has developed a harmonized, limited observational dataset abstracted from electronic health record data comprising a retrospective cohort of individuals aged 35 to 89 years who were affiliated with these healthcare systems from January 1, 2010, through September 30, 2019 to conduct research aimed at identifying and addressing critical gaps in the LCS process. The KPCO Institutional Review Board of record for PROSPR-Lung approved this study and waived the requirement for written informed consent.

We identified 7,960 adults who underwent LCS with a baseline LDCT between January 1, 2015 and September 30, 2017. We limited our study inclusion period to ensure that all individuals had a minimum of 24 months of follow-up after their baseline screens (i.e., follow-up through September 30, 2019). We additionally restricted our cohort to those who had documented healthcare engagement within 24 months of the baseline screen. Consistent with the CMS LCS age criteria of 55 to 77 years and our requirement for a 24-month minimum follow-up period, we included adults aged 55 to 75 years at time of baseline LDCT who currently or formerly smoked (8). Individuals with baseline screens missing Lung-RADS scores and those diagnosed with lung cancer before baseline screens were excluded. We also excluded those who died during the period of adherence ascertainment. Assembly of the analytic sample is summarized in Figure 1.

Variables

The primary outcome was adherence to Lung-RADS recommendations after a baseline screen (Table 1). For individuals with negative baseline screens (Lung-RADS 1 or 2), we defined adherence to annual LCS as any repeat CT chest scan within 10–15 months of the baseline LDCT, consistent with the definition previously used by others (21, 27). We defined adherence to recommended follow-up care as any CT chest scan within 4–9 months for Lung-RADS 3, any CT chest scan or positron emission tomography (PET)/CT within 1–5 months for Lung-RADS 4A, and any CT chest scan, PET/CT, or biopsy within 5 months for Lung-RADS 4B or 4X screens, respectively (27). A broad range of imaging and procedural codes were used to capture adherence (online supplement). We also performed sensitivity analyses using alternate definitions of adherence to facilitate comparisons to published rates on adherence (9, 22, 26, 27).

Consistent with previously established definitions of types of LCS programs (26, 34), we categorized LCS programs as centralized

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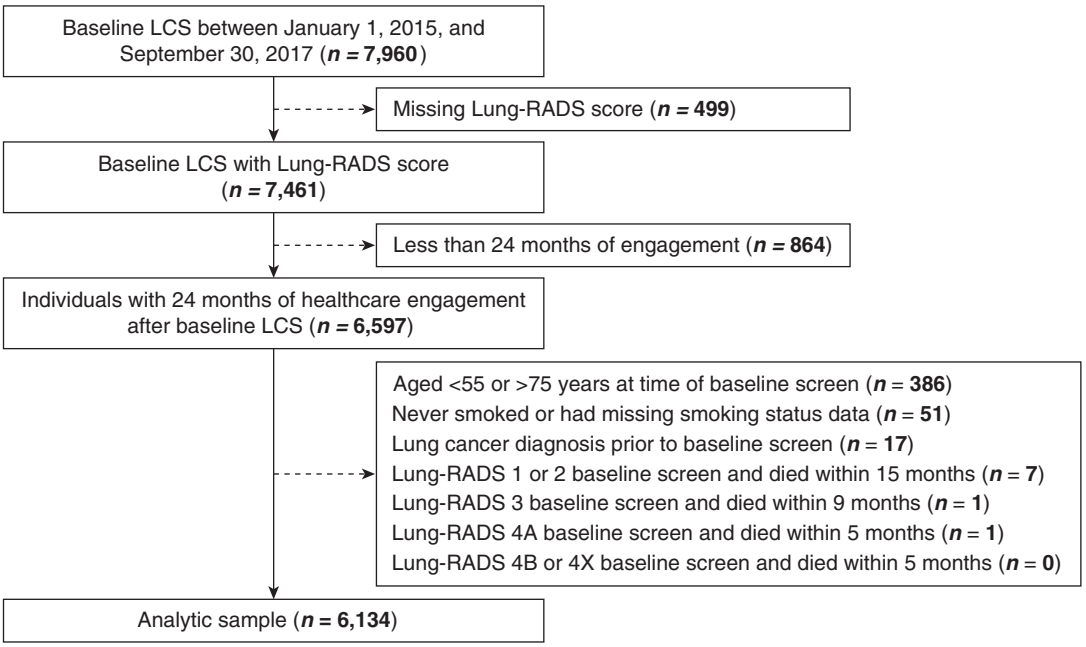

Figure 1. Assembly of the analytic sample. LCS = lung cancer screening; Lung-RADS = Lung Imaging Reporting and Data System.

or decentralized. At sites with centralized programs (KPCO and KPHI), trained navigators placed LDCT orders, reported results, and provided patients with follow-up reminders; at those with decentralized programs (HFHS, MCHS, and UPHS), primary care or specialty providers were responsible for these tasks (33). Individual-level covariates available for analysis included baseline screen Lung-RADS score, age, sex, race and ethnicity, smoking status, Charlson comorbidity index (35, 36), body mass index (BMI), and year of baseline screen. Race and ethnicity was ascertained from electronic health record data (37). Census tract covariates included median annual family income and highest level of education achieved.

Statistical Analysis

We used descriptive statistics to evaluate patient demographics and clinical characteristics. Continuous variables were described with medians and interquartile ranges (IQRs) and categorical variables with frequencies and percentages. We calculated adherence as the proportion of screened individuals adherent to Lung-RADS recommendations stratified by baseline screen result and type of LCS program. We reported raw adherence percentages by baseline characteristics as unadjusted proportions. We evaluated differences in adherence by type of LCS program and patient race using the Pearson chi-square test.

To assess the relationship between patient race and adherence to annual LCS and follow-up recommendations by type of LCS program, we performed stratified analyses using multivariable modified Poisson regression to estimate adjusted

Table 1. Definition of adherence to Lung Imaging Reporting and Data System recommendations

Lung-RADS Score	Category Descriptor	Lung-RADS Recommendation	Study Definition of Adherence
Negative baseline screen			
1	Negative	12 mo LDCT	10–15 mo any CT chest scan*
2	Benign		
Positive baseline screen			
3	Probably benign	6 mo LDCT	4–9 mo any CT chest scan*
4A	Probably suspicious	3 mo LDCT; PET/CT if ⩾8 mm solid component	1–5 mo any CT chest scan* or PET/CT scan
4B 4X	Suspicious	Chest CT, PET/CT, and/or biopsy	0–5 mo any CT chest scan,* PET/CT scan, or biopsy†

Definition of abbreviations: CT = computed tomography; LDCT = low-dose computed tomography; Lung-RADS = Lung Imaging Reporting and Data System; PET/CT = positron emission tomography/computed tomography.
*Included LDCT, chest CT with or without intravenous contrast, and chest CT angiography.
†Included bronchoscopy, mediastinoscopy, and percutaneous, surgical, pleural, and lymph node biopsy.

relative risks (aRRs) and 95% confidence intervals (CIs) (38, 39). We *a priori* included an interaction term for type of LCS program and race in all models. All other baseline covariates were included in the final multivariable models, as they represented possible confounders for the association with adherence (13). The individual effects of study sites were modeled as random effects to account for heterogeneity. We used multiple imputation by chained equations to impute missing values for race and ethnicity (2.7%), BMI (0.8%), median family income (1.2%), and education (1.1%) (40). Based on our original dataset, we generated 10 multiply imputed datasets, and estimates from these datasets were combined using standard methods provided in Stata/MP 17.0 (41). All regression models were fitted on each imputed dataset and summarized across datasets using Rubin's rule (40). We also performed sensitivity analyses—one limited to individuals with complete data and four others using alternate definitions of adherence to Lung-RADS recommendations (9, 22, 26, 27).

All statistical tests were two-sided, and a $P < 0.05$ was considered statistically significant. All analyses were conducted using Stata/MP 17.0.

Results

Baseline Characteristics

Of the 6,134 adults screened for lung cancer, 5,142 (83.8%) and 992 (16.2%) had negative and positive baseline screens, respectively. Among individuals with negative baseline screens, 2,747 (53.4%) and 2,395 (46.6%) were screened at decentralized and centralized LCS programs, respectively (*see* Table E1 in the online supplement). Most patients had a Lung-RADS 2 baseline screen (3,738 [72.7%]). The median age (IQR) was 65 (60–69) years, and 2,343 (45.6%) patients were identified as female, 729 (14.2%) as Black, 234 (4.6%) as Hispanic, 222 (4.3%) as Asian, and 3,039 (59.1%) as currently smoking. Although a similar proportion of White individuals were screened at each type of program, minority populations differed across healthcare systems, such that more Black individuals were screened at decentralized programs and more individuals of Hispanic, Asian, Native Hawaiian, or Pacific Islander race or ethnicity at centralized programs.

Among patients with positive baseline screens, 440 (44.4%) and 552 (55.6%) were screened at decentralized and centralized programs, respectively (Table E2). Most patients had a Lung-RADS 3 baseline screen (640 [64.5%]). The median age (IQR) was 66 (61–70) years, and 451 (45.5%) were identified as female, 110 (11.1%) as Black, 49 (4.9%) as Hispanic, 25 (2.5%) as Asian, and 583 (58.8%) as currently smoking.

Adherence to Annual LCS (Negative Baseline Screen)

Overall adherence to annual LCS after a negative baseline screen was 54.1% (2,779 of 5,142). Adherence was 34.8% (957 of 2,747) and 76.1% (1,822 of 2,395) at decentralized and centralized programs, respectively ($P < 0.001$). Although adherence to annual LCS was significantly lower among Black (23.8% [153 of 644]) than White (39.0% [745 of 1,912]) adults at decentralized programs ($P < 0.001$), this racial disparity was attenuated and not statistically significant at centralized programs (71.8% [61 of 85] vs. 75.7% [1,290 of 1,704]; $P = 0.410$). Overall annual LCS adherence by baseline covariates and stratified by type of program are displayed in Table 2. Among individuals adherent to annual LCS, LDCT comprised 82.7% (4,695 of 5,675) and diagnostic CT chest scans 17.3% (980 of 5,675) of all follow-up imaging, respectively (Table E3). Table E4 summarizes estimates of adherence to annual LCS using alternate definitions of adherence to Lung-RADS 1 or 2 recommendations.

Adherence to Recommended Follow-Up Care (Positive Baseline Screen)

Overall adherence to follow-up recommendations after a positive baseline screen was 69.9% (693 of 992). Adherence was 63.9% (281 of 440) and 74.6% (412 of 552) at decentralized and centralized programs, respectively ($P < 0.001$). At decentralized programs, no statistically significant difference in adherence to recommended follow-up care between Black (62.9% [56 of 89]) and White (63.9% [212 of 332]) individuals was observed ($P = 0.871$). This absence of a significant difference by race was also observed at centralized programs (61.9% [13 of 21] vs. 75.3% [317 of 421]; $P = 0.169$). Overall adherence to follow-up recommendations by baseline covariates and stratified by type of program are displayed in Table 3. Among adherent individuals with Lung-RADS 3 baseline screens, diagnostic CT chest scans and LDCT made up 88.2% (788 of 893) and 11.8% (105 of 893) of all follow-up imaging, respectively. Diagnostic CT chest scans (86.3% [295 of 342]) and PET/CT (9.6% [33 of 342]) were most common among those adherent to Lung-RADS 4A follow-up recommendations, and biopsy procedures (53.9% [279 of 518]) among those with Lung-RADS 4B or 4X screens (Table E3). Adherence estimates using alternate definitions of adherence to Lung-RADS 3 or 4 recommendations are summarized in Table E4.

Multivariable Adjusted Associations of Patient Race with Adherence to Annual LCS and Recommended Follow-Up Care

Figure 2 summarizes the association of race with adherence to annual LCS and recommended follow-up care after adjustment for all other baseline characteristics, stratified by type of LCS program. Among individuals with negative baseline screens, a racial disparity in adherence was observed only at decentralized screening programs (interaction term, $P < 0.001$). At decentralized programs, Black race was associated with 27% reduced adherence to annual LCS (aRR, 0.73; 95% CI, 0.63–0.84), whereas at centralized programs, no effect by race was observed (aRR, 0.98; 95% CI, 0.91–1.05). In contrast, among adults with positive baseline screens, there was no statistically significant difference in racial disparity for adherence to recommended follow-up care by type of LCS program (interaction term, $P = 0.176$; decentralized aRR, 0.95; 95% CI, 0.81–1.11; centralized aRR, 0.81; 95% CI, 0.71–0.93).

Adjusted estimates of adherence to annual LCS and recommended follow-up care among Black and White patients are summarized in Table 4. Sensitivity analyses limited to individuals with complete case data and using alternate definitions of adherence to Lung-RADS recommendations yielded similar results (Table E5).

Discussion

In this multicenter cohort study of adults undergoing routine LCS at decentralized and centralized programs within five diverse healthcare systems, we evaluated both adherence to annual LCS after a negative baseline screen and recommended follow-up care after a positive baseline screen. Black

Table 2. Adherence to annual lung cancer screening among individuals with a negative baseline screen, overall and by type of screening program

Variable	Overall (*N* = *5,142*)	Decentralized (*n* = *2,747*)	Centralized (*n* = *2,395*)
Overall adherence	54.1 (2,779/5,142)	34.8 (957/2,747)	76.1 (1,822/2,395)
Baseline Lung-RADS score			
1	47.5 (667/1,404)	29.1 (255/875)	77.9 (412/529)
2	56.5 (2,112/3,738)	37.5 (702/1,872)	75.6 (1,410/1,866)
Age, yr			
55–60	45.9 (633/1,379)	28.8 (237/822)	71.1 (396/557)
61–65	53.1 (781/1,470)	33.2 (262/788)	76.1 (519/682)
66–69	58.8 (707/1,203)	38.0 (228/600)	79.4 (479/603)
70–75	60.4 (658/1,090)	42.8 (230/537)	77.4 (428/553)
Sex			
Female	52.0 (1,219/2,343)	35.1 (467/1,330)	74.2 (752/1,013)
Male	55.7 (1,560/2,799)	34.6 (490/1,417)	77.4 (1,070/1,382)
Race or ethnicity			
White	56.3 (2,035/3,616)	39.0 (745/1,912)	75.7 (1,290/1,704)
Black	29.4 (214/729)	23.8 (153/644)	71.8 (61/85)
Hispanic	65.0 (152/234)	9.1 (2/22)	70.8 (150/212)
Asian	80.2 (178/222)	29.2 (7/24)	86.4 (171/198)
Native Hawaiian or Pacific Islander	79.3 (73/92)	20.0 (1/5)	82.8 (72/87)
American Indian or Alaska Native	76.0 (19/25)	42.9 (3/7)	88.9 (16/18)
Not specified	54.2 (45/83)	33.3 (11/33)	68.0 (34/50)
Smoking status			
Current	50.3 (1,530/3,039)	31.2 (527/1,688)	74.2 (1,003/1,351)
Former	59.4 (1,249/2,103)	40.6 (430/1,059)	78.4 (819/1,044)
Charlson comorbidity index			
0	50.2 (964/1,922)	30.7 (337/1,097)	76.0 (627/825)
1	55.3 (851/1,540)	36.6 (301/823)	76.7 (550/717)
⩾2	57.4 (964/1,680)	38.6 (319/827)	75.6 (645/853)
Body mass index, kg/m^2			
⩽24.9	57.0 (877/1,539)	34.8 (250/719)	76.5 (627/820)
25.0–29.9	54.4 (943/1,735)	34.4 (310/901)	75.9 (633/834)
⩾30	51.9 (948/1,826)	35.6 (387/1,086)	75.8 (561/740)
Year of baseline screen			
2015	62.9 (748/1,189)	39.9 (162/406)	74.8 (586/783)
2016	54.6 (1,108/2,029)	31.9 (349/1,093)	81.1 (759/936)
2017	48.0 (923/1,924)	35.7 (446/1,248)	70.6 (477/676)
Median family income,* $			
11,630–60,172	39.2 (503/1,282)	27.0 (253/938)	72.7 (250/344)
60,181–78,950	55.0 (693/1,261)	41.4 (295/713)	72.6 (398/548)
78,952–104,545	59.3 (746/1,259)	35.1 (181/515)	75.9 (565/744)
104,649–250,001	63.6 (812/1,276)	39.6 (206/520)	80.2 (606/756)
Highest level of education*			
High school or less	49.3 (1,391/2,819)	34.1 (607/1,780)	75.5 (784/1,039)
Some college or higher	60.3 (1,366/2,266)	36.0 (328/910)	76.5 (1,038/1,356)

Definition of abbreviation: Lung-RADS = Lung Imaging Reporting and Data System.
Adherence to Lung-RADS recommendations is displayed as percentage adherent (number of individuals/total number). Study sites with decentralized programs included Henry Ford Health System, Marshfield Clinic Health System, and University of Pennsylvania Health System, and those with centralized programs included Kaiser Permanente Colorado and Kaiser Permanente Hawaii.
*Census tract data.

patients were less likely to receive annual LCS than White patients after a negative baseline screen at decentralized compared with centralized LCS programs. Conversely, this racial disparity was not significantly different by type of LCS program when we assessed adherence to recommended follow-up care among individuals with a positive baseline screen. To our knowledge, this is the first study to identify an effect of program centralization on mitigating racial disparity in annual LCS care.

As recently suggested by others (9, 30, 42, 43), it is critical for the lung cancer scientific research community to progress beyond simply proving that disparities exist and begin to investigate how to eliminate them. A first step toward achieving this goal is to further elucidate healthcare system–level factors that promote high-quality care for all patients. That centralization of the LCS process was associated with attenuation of racial disparities in annual LCS care demonstrates the importance of programmatic features in standardizing LCS care. In our study, adherence to annual LCS was 76% at centralized screening programs, compared with a median adherence of 59% reported in a recent meta-analysis (30) and adherence estimates ranging from 46% to 70% (26, 27, 29) reported in subsequently published studies assessing adherence at centralized programs. On the other hand, annual adherence was significantly lower at 35% among those screened at decentralized programs, consistent with estimates ranging

Table 3. Adherence to recommended lung cancer screening follow-up care among individuals with a positive baseline screen, overall and by type of screening program

Variable	Overall (*N* = 992)	Decentralized (*n* = 440)	Centralized (*n* = 552)
Overall adherence	69.9 (693/992)	63.9 (281/440)	74.6 (412/552)
Baseline Lung-RADS score			
3	64.8 (415/640)	55.5 (147/265)	71.5 (268/375)
4A	73.2 (172/235)	67.2 (80/119)	79.3 (92/116)
4B or 4X	90.6 (106/117)	96.4 (54/56)	85.2 (52/61)
Age, yr			
55–60	72.1 (155/215)	67.0 (71/106)	77.1 (84/109)
61–65	68.8 (187/272)	60.3 (76/126)	76.0 (111/146)
66–69	69.8 (173/248)	65.1 (69/106)	73.2 (104/142)
70–75	69.3 (178/257)	63.7 (65/102)	72.9 (113/155)
Sex			
Female	72.7 (328/451)	62.4 (133/213)	81.9 (195/238)
Male	67.5 (365/541)	65.2 (148/227)	69.1 (217/314)
Race or ethnicity			
White	70.3 (529/753)	63.9 (212/332)	75.3 (317/421)
Black	62.7 (69/110)	62.9 (56/89)	61.9 (13/21)
Hispanic	71.4 (35/49)	50.0 (1/2)	72.3 (34/47)
Asian	76.0 (19/25)	100.0 (2/2)	73.9 (17/23)
Native Hawaiian or Pacific Islander	100.0 (9/9)	—	100.0 (9/9)
American Indian or Alaska Native	75.0 (6/8)	100.0 (1/1)	71.4 (5/7)
Not specified	66.7 (10/15)	—	66.7 (10/15)
Smoking status			
Current	67.2 (392/583)	61.1 (165/270)	72.5 (227/313)
Former	73.6 (301/409)	68.2 (116/170)	77.4 (185/239)
Charlson comorbidity index			
0	65.6 (238/363)	60.7 (108/178)	70.3 (130/185)
1	71.1 (219/308)	62.3 (81/130)	77.5 (138/178)
⩾2	73.5 (236/321)	69.7 (92/132)	76.2 (144/189)
Body mass index, kg/m^2			
⩽24.9	70.3 (246/350)	64.3 (92/143)	74.4 (154/207)
25.0–29.9	70.0 (236/337)	63.1 (89/141)	75.0 (147/196)
⩾30	70.2 (207/295)	65.8 (96/146)	74.5 (111/149)
Year of baseline screen			
2015	71.9 (192/267)	63.1 (41/65)	74.8 (151/202)
2016	70.9 (248/350)	68.0 (119/175)	73.7 (129/175)
2017	67.5 (253/375)	60.5 (121/200)	75.4 (132/175)
Median family income,* $			
11,630–60,172	68.8 (161/234)	64.4 (87/135)	74.7 (74/99)
60,181–78,950	67.6 (173/256)	64.0 (89/139)	71.8 (84/117)
78,952–104,545	72.5 (185/255)	68.2 (60/88)	74.9 (125/167)
104,649–250,001	71.4 (170/238)	60.0 (42/70)	76.2 (128/168)
Highest level of education*			
High school or less	69.4 (359/517)	64.2 (183/285)	75.9 (176/232)
Some college or higher	70.9 (331/467)	64.6 (95/147)	73.8 (236/320)

Definition of abbreviation: Lung-RADS = Lung Imaging Reporting and Data System.
Adherence to Lung-RADS recommendations is displayed as percentage adherent (number of individuals/total number). Study sites with decentralized programs included Henry Ford Health System, Marshfield Clinic Health System, and University of Pennsylvania Health System, and those with centralized programs included Kaiser Permanente Colorado and Kaiser Permanente Hawaii.
*Census tract data.

from 35% to 46% (25, 26, 29, 30) reported in recent publications. Our results are potentially explained by differences in the management processes that exist within centralized and decentralized screening programs. At decentralized centers, the management of LCS findings is left to the discretion of the ordering provider. The identification of abnormal findings often prompts the ordering of subsequent imaging or referral to a specialist for further evaluation. As negative results do not trigger an obvious subsequent evaluation, ordering of LDCT for annual screening may only be captured opportunistically at future visits. In contrast, at centralized programs, dedicated navigators conducted shared-decision-making visits, placed LDCT orders, and managed screening results. However, as both centralized LCS programs included in our study were affiliated with integrated healthcare systems, we are unable to conclude whether the superior adherence rates and reduced racial disparity we observed at these sites were a result of components of LCS program–specific or overall healthcare system processes. Notably a recent single-center study evaluating a centralized LCS program within a nonintegrated healthcare system found that Black patients had significantly reduced rates of annual LCS compared with White patients (23). The investigators noted that a referral

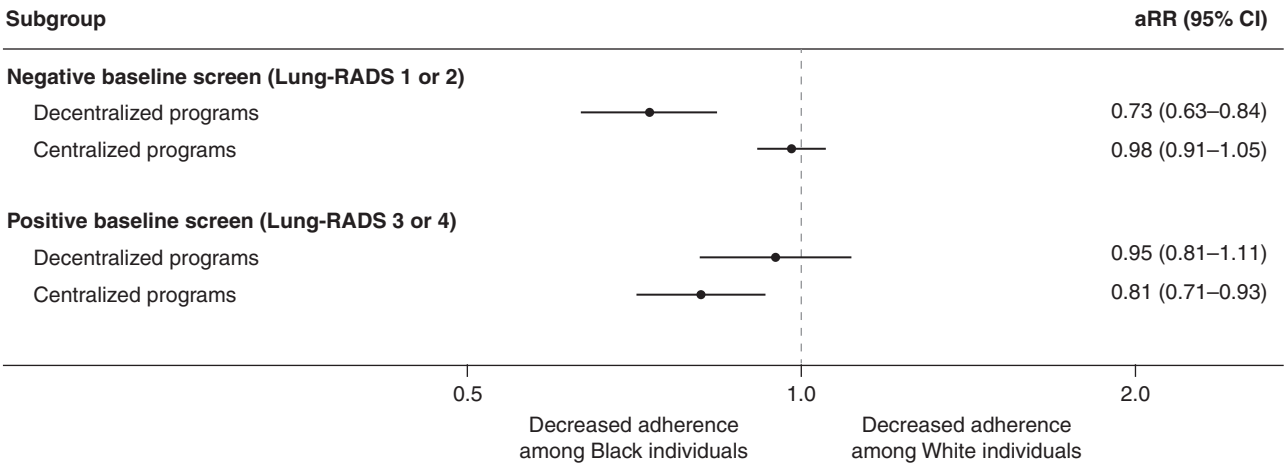

Figure 2. Association of race with adherence to annual lung cancer screening (Lung Imaging Reporting and Data System [Lung-RADS] 1 or 2) and recommended follow-up care (Lung-RADS 3 or 4) stratified by type of screening program. Dots illustrate adjusted relative risk (aRR) effect estimates for Black versus White race and horizontal lines, 95% confidence intervals (CIs). The vertical dashed line represents the null hypothesis of aRR = 1.0. Models included an interaction term for race and type of lung cancer screening program and were adjusted for baseline screen Lung-RADS score, age, sex, smoking status, Charlson comorbidity index, body mass index, year of baseline screen, median family income, and highest level of education. Study site heterogeneity was modeled as random effects.

bias may have been present, because patients could only be entered into the LCS program after being referred by a healthcare provider. Because most participants diagnosed with lung cancer in both the NLST and NELSON trials had a negative baseline scan during the first round of screening (1, 2), further investigation of mechanisms to improve adherence rates among individuals with negative screens is crucial, especially among those screened at decentralized programs.

Apart from LCS programmatic factors, our finding that Black patients with negative baseline screens were less likely to receive an annual scan additionally raises the possibility of structural racism underlying this disparity. Inequities in social determinants of health (e.g., healthcare literacy, medical mistrust, patient–provider communication, experienced discrimination, and transportation availability) have been hypothesized to contribute to racial disparities in use of imaging services (44). Previous studies have reported reduced knowledge of both lung cancer risk and LCS among Black individuals (45, 46) and less frequent healthcare provider communication of radiology results with Black patients (42). It will be critical for future studies to identify additional specific barriers to care and for healthcare systems and individual providers to address these systemic shortcomings to reduce disparities in LCS (47).

We found that adherence to recommended follow-up care among individuals with positive baseline screens was higher at centralized programs overall relative to decentralized programs (75% vs. 64%) but did not detect a significant difference in racial disparity in adherence by type of LCS program. Our results are consistent with a recent prior study, which also demonstrated a reduction in racial disparity among patients with positive compared with negative baseline screen results (23). The overall rates of adherence to recommended follow-up care we report here are comparable to those reported in prior studies, which have ranged from 61% to 100% (17, 21–24, 27). Although it is difficult to draw clear conclusions from these results given the heterogeneous clinical management decisions that might be appropriate for individual patients based on a variety of factors (e.g., underlying comorbidities, patient preferences, tolerance for procedural risk, desire for potential lung cancer treatment), it is reassuring that we observed overall increased adherence among patients with positive compared with

Table 4. Adjusted adherence by race, stratified by baseline screen result and type of screening program

	Adjusted Adherence,* % (95% CI)			
	Negative Baseline Screen (Lung-RADS 1 or 2)		Positive Baseline Screen (Lung-RADS 3 or 4)	
Race	Decentralized	Centralized	Decentralized	Centralized
White	34.0 (31.7–36.3)	84.8 (80.1–89.6)	57.5 (50.0–64.9)	83.7 (74.0–93.4)
Black	25.2 (21.4–28.9)	83.1 (71.3–94.9)	54.7 (43.8–65.6)	67.8 (45.0–90.5)

Definition of abbreviations: CI = confidence interval; Lung-RADS = Lung Imaging Reporting and Data System.
Study sites with decentralized programs included Henry Ford Health System, Marshfield Clinic Health System, and University of Pennsylvania Health System, and those with centralized programs included Kaiser Permanente Colorado and Kaiser Permanente Hawaii.
*Based on the results of the multivariable modified Poisson regression models.

negative baseline screens, especially at decentralized programs. Even so, that >20% of patients screened at centralized programs did not receive recommended follow-up care after a positive screen suggests that further optimization of the LCS process beyond program centralization may be required.

Strengths and Limitations

A major strength of our analysis is its generalizability, as it represents one of the largest multicenter cohort studies to assess adherence to both annual LCS and recommended follow-up care. We additionally used a clinically relevant definition of adherence that reflects real-world conditions and restricted our analysis to a period when Lung-RADS was being widely used. Importantly, we used a broad range of imaging and procedural codes to capture adherence. For example, instead of solely using codes for LDCT scans among patients with negative baseline screens to determine annual LCS adherence, we additionally included diagnostic chest CT scans in our definition. In clinical practice, if a patient were to incidentally receive a diagnostic chest CT for unrelated reasons within the appropriate time frame for annual LCS, providers would not need to additionally order a follow-up LDCT to meet requirements for annual LCS.

Our study has limitations. First, as with all observational studies, the possibility of unmeasured confounding cannot be excluded. For example, we were unable to assess the impact of insurance, individual-level socioeconomic variables, or individual providers, particularly within decentralized programs. Second, as race and ethnicity was ascertained from electronic health record data and not from patient self-reporting, the possibility of misclassification exists (48); however, prior studies have demonstrated that misclassification of non-Hispanic White and non-Hispanic Black race may be less prevalent than that of other races and ethnicities (48–51). This influenced our decision to restrict our analysis of racial disparity to Black and White patients. In addition, although our multicenter cohort encompasses patients across five states, it has limited representation of individuals of non-Black and non-White races and ethnicities. As this population represents a heterogeneous group of individuals who are known to experience distinct disparities in LCS (52), we elected not to collate these patients into a single category despite the ability to do so from a statistical analysis perspective (53). It will be important for future studies to further examine these minority populations. Third, although we used standardized data extraction methods across all study sites to generate a single, harmonized dataset for analysis, some variables were missing data. For example, our dataset did not include complete smoking history variables such as pack-years and quit date among individuals who formerly smoked, so we were unable to adjust for these factors. However, among variables missing <3% data, we used multiple imputation to account for incomplete data and performed a sensitivity analysis limited to individuals with complete information. Finally, as we did not have detailed clinical information available regarding life expectancy, goals of care, or preference to pursue further invasive diagnostic testing, we were unable to fully evaluate the mechanisms that resulted in nonadherence for individuals.

Conclusions

Adherence to both annual LCS and recommended follow-up care in our large multicenter cohort of real-world individuals receiving LCS was increased at centralized compared with decentralized LCS programs. Black patients were less likely to receive annual LCS than White patients at decentralized compared with centralized LCS programs. Our results highlight differential patterns of adherence by type of screening program and encourage further study of additional mechanisms that contribute to poor adherence. Moreover, there is a critical need to develop effective and sustainable approaches for ensuring adherence to LCS across diverse populations. ■

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