Original Article

Racial disparities in staging, treatment, and mortality in non-small cell lung cancer

Francesca C. Duncan[1]^, Nawar Al Nasrallah[1]^, Lauren Nephew[2]^, Yan Han[3], Andrew Killion[4], Hao Liu[5], Ahmad Al-Hader[6], Catherine R. Sears[1,7]^

[1]Division of Pulmonary, Critical Care, Sleep and Occupational Medicine, Indiana University School of Medicine, Indianapolis, IN, USA; [2]Division of Gastroenterology and Hepatology, Indiana University School of Medicine, Indianapolis, IN, USA; [3]Department of Biostatistics and Health Data Science, Indiana University School of Medicine, Indianapolis, IN, USA; [4]Indiana Clinical and Translational Science Institute, Indiana University School of Medicine, Indianapolis, IN, USA; [5]Department of Biostatistics and Epidemiology, Rutgers Cancer Institute of New Jersey, Rutgers School of Public Health, New Brunswick, NJ, USA; [6]Division of Hematology and Oncology, Indiana University School of Medicine, Indianapolis, IN, USA; [7]Division of Pulmonary Medicine, Richard L. Roudebush Veterans Affairs Medical Center, Indianapolis, IN, USA

Contributions: (I) Conception and design: FC Duncan, N Al Nasrallah, L Nephew, CR Sears; (II) Administrative support: FC Duncan, CR Sears; (III) Provision of study materials or patients: A Al-Hader; (IV) Collection and assembly of data: FC Duncan, A Al-Hader, A Killion; (V) Data analysis and interpretation: Y Han, A Killion, H Liu; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

Correspondence to: Catherine R. Sears, MD. Division of Pulmonary, Critical Care, Sleep and Occupational Medicine, Indiana University School of Medicine, 980 W. Walnut St., Room C400, Indianapolis, IN 46202, USA; Division of Pulmonary Medicine, Richard L. Roudebush Veterans Affairs Medical Center, Indianapolis, IN, USA. Email: crufatto@iu.edu.

Background: Black race is associated with advanced stage at diagnosis and increased mortality in non-small cell lung cancer (NSCLC). Most studies focus on race alone, without accounting for social determinants of health (SDOH). We explored the hypothesis that racial disparities in stage at diagnosis and outcomes are associated with SDOH and influence treatment decisions by patients and providers.

Methods: Patients with NSCLC newly diagnosed at Indiana University Simon Comprehensive Cancer Center (IUSCCC) from January 1, 2000 to May 31, 2015 were studied. Multivariable regression analyses were conducted to examine the impact of SDOH (race, gender, insurance status, and marital status) on diagnosis stage, time to treatment, receipt of and reasons for not receiving guideline concordant treatment, and 5-year overall survival (OS) based on Kaplan-Meier curves.

Results: A total of 3,349 subjects were included in the study, 12.2% of Black race. Those diagnosed with advanced-stage NSCLC had a significantly higher odds of being male, uninsured, and Black. Five-year OS was lower in those of Black race, male, single, uninsured, Medicare/Medicaid insurance, and advanced stage. Adjusted for multiple variables, individuals with Medicare, Medicare/Medicaid, uninsured, widowed, and advanced stage at diagnosis, were associated with significantly lower OS time. Black, single, widowed, and uninsured individuals were less likely to receive stage appropriate treatment for advanced disease. Those uninsured [odds ratio (OR): 3.876, P<0.001], Medicaid insurance (OR: 3.039, P=0.0017), and of Black race (OR: 1.779, P=0.0377) were less likely to receive curative-intent surgery for early-stage NSCLC because it was not a recommended treatment.

Conclusions: We found racial, gender, and socioeconomic disparities in NSCLC diagnosis stage, receipt of stage-appropriate treatment, and reasons for guideline discordance in receipt of curative intent surgery for early-stage NSCLC. While insurance type and marital status were associated with worse OS, race alone was not. This suggests racial differences in outcomes may not be associated with race alone, but rather worse SDOH disproportionately affecting Black individuals. Efforts to understand advanced diagnosis and reasons

^ ORCID: Francesca C. Duncan, 0000-0002-3968-6586; Nawar Al Nasrallah, 0000-0002-6507-8859; Lauren Nephew, 0000-0003-0837-0746; Catherine R. Sears, 0000-0002-5797-3458.

for failure to receive stage-appropriate treatment by vulnerable populations is needed to ensure equitable NSCLC care.

Keywords: Race; lung cancer; surgery; insurance; socioeconomic

Submitted Jun 21, 2023. Accepted for publication Jan 12, 2024. Published online Jan 29, 2024.
doi: 10.21037/tlcr-23-407
View this article at: https://dx.doi.org/10.21037/tlcr-23-407

Introduction

Background

Lung cancer is the leading cause of cancer mortality in the United States (U.S.), comprising 21% of all cancer deaths (1). While lung cancer deaths continue to decline due to advances in early detection through lung cancer screening and improved treatments for advanced disease (2,3), Black individuals and those from low socioeconomic groups continue to be disproportionately affected with higher incidence and mortality rates compared to White individuals (1,4). In the U.S., mortality is substantially higher for Black men compared to the national average (54 *vs.* 44.5 deaths per 100,000 cases), and even higher in the state of Indiana, which has some of the highest mortality rates for Black men in the country (1). The ability to access cancer screening and treatment is greatly influenced by social determinants of health (SDOH) (4-6). The SDOH are the non-medical factors that influence health outcomes. They include the conditions and environments where people live, learn, work and play, but also their race, ethnicity, and social support (7).

Highlight box

Key findings
- Racial disparities in non-small cell lung cancer (NSCLC) are associated with socioeconomic factors that influence diagnosis stage, treatment, and reasons for not receiving guideline concordant surgery for early-stage disease.

What is known and what is new?
- Black individuals with NSCLC have worse survival; however, marital and insurance status contribute to observed disparities.
- Black, widowed, Medicaid, Medicare, and uninsured individuals were less likely to receive curative intent surgery for early-stage NSCLC.
- Black, single, widowed, uninsured, Medicaid, Medicare, and Medicaid/Medicare individuals were less likely to receive stage appropriate treatment for advanced-stage NSCLC.
- Black, Medicaid, and uninsured individuals were less likely to be recommended surgery for early-stage NSCLC. Non-married status was associated with surgery refusal.

What is the implication, and what should change now?
- Identification of modifiable causes of racial disparities is needed to target interventions to mitigate late diagnosis and failure to receive stage-appropriate treatment.

Rationale and knowledge gap

Outcomes in non-small cell lung cancer (NSCLC), like other cancers, have been previously shown to be affected by SDOH. For instance, insurance status is a SDOH that has been linked to disparities in lung cancer diagnosis and outcomes. In the U.S., Medicaid is a type of public insurance funded jointly by individual states and the federal government and provides health coverage to nearly 85 million Americans, including low income adults, elderly adults, and people with disabilities (8). Medicare, another public health insurance, funds Americans aged 65 and older, certain younger people with disabilities, and those with end-stage renal disease requiring dialysis or transplant. Differences in oncologic outcomes have been suggested in those with Medicaid, Medicare and both public insurances (9). For instance, in a study using the National Cancer Database, Namburi *et al.* showed that patients insured by Medicaid and from low-income areas were less likely to receive curative surgery and had worse long-term overall survival (OS) (5).

Standard therapy for clinical stage I NSCLC is lobectomy with sampling or dissection of mediastinal lymph nodes (10). During the past decade, stereotactic ablative radiotherapy, also called SBRT, has become an option for inoperable and some operable clinical stage I NSCLC, although surgery remains the standard of care (11,12).

In single center studies of patients with stage I NSCLC, failure to undergo surgical resection was associated with low income, nonwhite race, education less than high

school, rural residence, and being uninsured or insured by Medicaid (13,14). Notably, these studies either were limited to early-stage NSCLC or did not assess how these SDOH-influenced providers' decisions to offer guideline-concordant treatment, or how the SDOH may be associated with patients' decisions regarding agreeing to recommended treatment. These studies were also unable to control for cigarette smoking status, an important mitigator of racial disparities in NSCLC (15,16).

Objective

Understanding the impact of SDOH on stage at diagnosis and mortality is necessary if targeted screening and cancer control efforts are to be developed. Therefore, the aims of this study were to explore the impact of the SDOH on NSCLC stage at diagnosis, receipt of stage appropriate treatment, reasons for not receiving stage appropriate treatment, timing of treatment onset, and 5-year OS. We hypothesized that observed racial disparities in stage at diagnosis may be mediated by SDOH other than race, and that the SDOH may influence patients' shared decision-making regarding treatment and impact treatment decisions among providers; thereby affecting outcomes. We present this article in accordance with the STROBE reporting checklist (available at https://tlcr.amegroups.com/article/view/10.21037/tlcr-23-407/rc).

Methods

Patient population

This study was conducted at Indiana University Melvin and Bren Simon Comprehensive Cancer Center, Indiana's only National Cancer Institute designated comprehensive cancer center, located in the Midwest region of the U.S. It was approved by Indiana University School of Medicine Institutional Review Board (IRB# 16613) using data from the Indiana University Simon Comprehensive Cancer Center Registry (IUSCCC). The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). Individual consent for this retrospective analysis was waived. The registry is comprised of patients with NSCLC diagnosed and treated at Indiana University Melvin and Bren Simon Comprehensive Cancer Center, an urban Midwest academic medical center. The cohort included all individuals over the age of 18, with newly diagnosed NSCLC between January 1, 2000 and May 31, 2015. Individuals with non-lung primary cancers metastasized to the lung, and those diagnosed and treated at sites other than IUH were excluded from this study. We did not include those diagnosed after 2015 because 5-year OS would have been confounded by the coronavirus disease 2019 (COVID-19) pandemic. In particular, studies showed a decline in patients undergoing cancer treatment during the COVID-19 pandemic (17-19). Further, those diagnosed with NSCLC were more likely to be diagnosed at a later stage during the COVID-19 pandemic compared to pre-COVID-19 (20,21).

Exposures

SDOH

Variables of interest included race, gender, marital status, and insurance type. Race, insurance status, marital status, and gender were considered as social constructs for this analysis (22), which may be associated with a patient's ability to access care and thus their overall cancer mortality. Patient race was defined according to Surveillance, Epidemiology, and End Results (SEER)'s race variable and categorized into Black and White. Those categorized as Other (2%), included Asian or Pacific Islander, and were excluded from the study due to small sample size. Ethnicity was classified as Hispanic and non-Hispanic and was used inclusively with race, as non-Hispanic ethnicity made up only 0.25% and 0.58% of Black and White race, respectively. Due to the small number of those identified as Hispanic ethnicity, we did not assess the association of ethnicity and outcomes of interest. Gender was self-reported and classified as male or female. Insurance type is a robust measure of both individual income and health care access (23). Insurance status was grouped into five categories: Medicaid only, Medicare only, Medicare and Medicaid, Self-pay/uninsured, and private. Those with both Medicare/Medicaid were analyzed separately based on studies suggesting this group has some of the worst OS rates (24-26). Private insurance was used as the reference for comparative analyses. Marital status was self-reported and classified as divorced or separated, married, single, and widowed. Those labeled "unknown" indicate the classification in the dataset at the time of initial data collection. To account for missing data, the total number ("n") is reflected in the tables for each category of interest.

Covariates

Other covariates captured from the IUSCCC included: age

at diagnosis and cigarette smoking status at diagnosis. Age at diagnosis was grouped into four categories: less than 40, 40–49, 50–64, and 65 years and older. Cigarette smoking status was categorized as currently smokes, formerly smoked, and never used.

The American Joint Committee on Cancer (AJCC) staging edition at the time of diagnosis (editions 5, 6, or 7) were used for NSCLC staging (27-29). For some therapeutic evaluations, staging was grouped into two categories: early (stage I or II) and advanced (stage III or IV). Tumor grade was classified as well-differentiated, moderately differentiated, poorly differentiated, undifferentiated, and unknown. Treatment type was grouped into three categories: surgery only, radiation only, and systemic therapy. Systemic therapy included chemotherapy, immunotherapy, or a combination of the two. Stage appropriate treatment was defined based on practice guidelines for NSCLC as determined by the American Society of Clinical Oncology (17). Early-stage disease standard of care treatment was defined as curative intent surgery. Receipt of radiation therapy (stereotactic body radiation therapy) was also investigated, as it is a potential alternative treatment for some early-stage NSCLC patients. Thus, we investigated the association of SDOH and the receipt of curative intent surgery and/or any radiation for early-stage disease. Advanced disease standard of care was defined as chemotherapy, immunotherapy, or a combination of both, with and without radiation.

Outcome measures

Our primary outcomes were: (I) NSCLC stage at diagnosis and (II) receipt of stage appropriate treatment while controlling for the SDOH. Secondary outcomes were (I) time from diagnosis to treatment; (II) 5-year OS; and (III) reasons for the lack of receipt of guideline concordant therapy for early-stage disease, controlling for SDOH. Reasons for failure to receive curative intent surgery were categorized as: (I) cancer directed surgery not performed because it was not a planned part of treatment; (II) cancer directed surgery not recommended as it was contraindicated due to other condition; (III) cancer directed surgery recommended but patient or guardian refused; and (IV) cancer directed surgery recommended, but not performed for unknown reason as it was not reported.

Statistical analysis

Categorical variables were summarized by frequency and percentage, while continuous variables were summarized by mean and standard deviation. The comparisons between (I) Black and White race; (II) early and advanced-stage; and (III) different insurance types were made by using Chi-square test or Fisher's exact test for categorical variables and analysis of variance (ANOVA) or nonparametric Kruskal-Wallis test for continuous variables. For the primary outcomes of stage at diagnosis and receipt of stage appropriate treatment, logistic regression models were used to evaluate the association between the SDOH and the outcomes. Univariable logistic regression models were performed and independent variables with P values <0.25 were selected for inclusion in the multivariable models. To study whether race was associated with the primary and secondary outcomes, race was always included in the multivariable models, so that the association was adjusted for other potential confounders. For the secondary outcomes of time from diagnosis to treatment onset and 5-year OS, Kaplan-Meier curves were plotted. The log-rank test was used to compare the time from diagnosis to the first treatment and 5-year OS between the SDOH variables race, gender, marital status, and insurance status, respectively. OS was defined as the time from the date of diagnosis to the date of death due to any reason. When the date of death was not known, the patient's OS was considered censored at the date of last contact. For the secondary outcome identifying reasons for the lack of receipt of curative intent surgery for early-stage NSCLC, multinomial logistic regression models were used to evaluate the association between the SDOH and reasons given for deviation from guideline concordant treatment. Univariable multinomial logistic regression models were first performed and covariates with P values <0.25 were selected for inclusion in the multivariable models. Race was always included in these multivariable models. Cox proportional hazards regression model was used to analyze the association between the SDOH and OS. Covariates were included in the multivariable Cox proportional hazards regression model if the P value was <0.25 in the univariable analysis. All analyses were performed using SAS v9.4 (Cary, NC, USA). P value less than 0.05 in the final regression model was considered statistically significant.

Results

Demographic and clinical characteristics

Of the 3,349 subjects with newly diagnosed NSCLC,

12.2% (n=408) of the cohort was of Black race and 0.5% of Hispanic ethnicity. Most subjects were 65 years old or older at the time of diagnosis. Black individuals were diagnosed at a younger age compared to White individuals (P=0.0003). Compared to White individuals, Black individuals were more likely to currently smoke cigarettes at the time of diagnosis (P=0.0041) and made up a greater percentage of those uninsured compared to White individuals (16.42% *vs.* 6.53%, respectively; P<0.0001). Black individuals also made up the greater majority of those with Medicaid insurance (15.93%) compared to White individuals (6.70%) (P<0.0001). Most White individuals (61.10%) in the cohort were married compared to only 29.56% of Black individuals (P<0.0001) (*Table 1*).

SDOH and stage at diagnosis

In the overall cohort, 59.24% of individuals were diagnosed with advanced-stage disease (*Table 1*). When exploring stage by the SDOH (gender, insurance, marital status, and race), 63.09% of men were diagnosed with advanced-stage NSCLC compared to 54.97% women (P<0.0001). Of those uninsured, 78.24% were diagnosed with advanced-stage NSCLC compared to 63.93% of those who were privately insured (P<0.0001). A greater percentage of single individuals were diagnosed with advanced-stage NSCLC compared to those who were married (69.64% *vs.* 58.09%, P<0.0001). Finally, 76.82% of Black individuals were diagnosed with advanced disease compared to 56.63% of White individuals (P<0.0001) (Table S1).

On univariable analysis, gender, current cigarette smoking status, insurance status, marital status, age, and race were all significantly associated with advanced stage at diagnosis (Table S2). On multivariable analysis male gender [odds ratio (OR): 1.460, 95% confidence interval (CI): 1.183–1.801, P=0.0004], uninsured status (OR: 1.710, 95% CI: 1.119–2.612, P=0.0131), and Black race (OR: 2.392, 95% CI: 1.653–3.461, P<0.0001) remained significantly associated with advanced stage at diagnosis after adjusting other covariates. Current smoking status tended to be associated with advanced stage at diagnosis, but this difference was not statistically significant (*Table 2*).

SDOH and receipt of curative intent surgery for early-stage NSCLC

In this cohort, 65.31% of individuals with early-stage disease received stage-appropriate curative intent surgery (Table S3). When explored by race, a smaller proportion of individuals of Black race received curative intent surgery for early-stage NSCLC compared to those of White race (P=0.0145). When considering SDOH (gender, insurance, marital status, age, and race) a greater percentage of those who received curative intent surgery had private insurance (38.48%) compared to individuals who were uninsured status (2.98%) or Medicaid insured (6.10%, P<0.0001). A greater percentage of those who received curative intent surgery for early-stage disease were married (64.17%), compared to single (9.13%) or widowed (8.99%) (P<0.0001) (Table S3).

On univariable analysis, insurance status, marital status, age, and race were associated with the failure to receive curative intent surgery in early-stage disease (Table S4). On multivariable analysis, those who were uninsured had a significantly lower odds of receiving curative intent surgery than those with private insurance (OR: 0.211, 95% CI: 0.105–0.425, P<0.0001). Those with Medicaid only (OR: 0.332, 95% CI: 0.172–0.639, P=0.0010) and Medicare only (OR: 0.661, 95% CI: 0.443–0.987, P=0.0432) also had a significantly lower odds of receiving curative intent surgery than those with private insurance. Widowed individuals had a significantly lower odds of receiving curative intent surgery for early-stage disease compared to married individuals (OR: 0.621, 95% CI: 0.418–0.923, P=0.0185). Adjusting for covariables, Black individuals had a significantly lower odds of receiving curative intent surgery for early-stage NSCLC compared to White individuals (OR: 0.562, 95% CI: 0.337–0.938, P=0.0274) (*Table 3*).

SDOH and reasons for failure to receive curative intent surgery for early-stage NSCLC

Among those diagnosed with early-stage NSCLC, 34.69% did not receive curative intent surgery (Table S3). To further identify root causes for disparate surgical treatment in early-stage NSCLC observed in the uninsured, Medicaid only, Medicare, widowed, and Black individuals, we explored the documented reason that surgery was not performed. When reasons were explored by insurance, multivariable analysis showed that those who had Medicaid only insurance (OR: 3.039, 95% CI: 1.516–6.092) and those uninsured (OR: 3.876, 95% CI: 1.808–8.311) had greater odds of not receiving curative intent surgery due to it "not being a planned part of treatment" compared to those with private insurance. Individuals with Medicare only had greater odds of not receiving curative intent surgery because

Table 1 Demographic and clinical characteristics of a cohort with newly diagnosed NSCLC at Indiana University Simon Comprehensive Cancer Center among Black and White individuals, 2000–2016

Variables	Overall	Black race	White race	P value
Age at diagnosis (years)[†]				0.0003*
<40	89 (2.66)	10 (2.45)	79 (2.69)	
40–49	320 (9.56)	58 (14.22)	262 (8.91)	
50–64	1,308 (39.06)	175 (42.89)	1,133 (38.52)	
≥65	1,632 (48.73)	165 (40.44)	1,467 (49.88)	
Gender[†]				0.4268
Male	1,728 (51.60)	203 (49.75)	1,525 (51.85)	
Female	1,621 (48.40)	205 (50.25)	1,416 (48.15)	
Ethnicity[‡]				0.5069
Hispanic	18 (0.54)	1 (0.25)	17 (0.58)	
Non-Hispanic	3,282 (98.06)	403 (98.77)	2,879 (97.96)	
Unknown	47 (1.40)	4 (0.98)	43 (1.46)	
AJCC stage at diagnosis[§]				<0.0001*
Early stage (stages I & II)				
Stage I	822 (24.54)	54 (15.08)	768 (31.81)	
Stage II	308 (9.20)	29 (8.10)	279 (11.56)	
Total	1,130 (40.76)	83 (23.18)	1,047 (43.37)	
Advanced stage (stages III & IV)				
Stage III	708 (21.14)	117 (32.68)	591 (24.48)	
Stages IV	934 (27.89)	158 (44.13)	776 (32.15)	
Total	1,642 (59.24)	275 (76.82)	1,367 (56.63)	
Tumor grade[†]				<0.0001*
Well differentiated	178 (5.32)	12 (2.94)	166 (5.64)	
Moderately differentiated	478 (14.27)	29 (7.11)	449 (15.27)	
Poorly differentiated	798 (23.83)	100 (24.51)	698 (23.73)	
Undifferentiated/anaplastic	51 (1.52)	3 (0.74)	48 (1.63)	
Unknown	1,844 (55.06)	264 (64.71)	1,580 (53.72)	
Cigarette use at time of diagnosis[¶]				0.0041*
Currently smoked	854 (44.83)	118 (53.64)	736 (43.68)	
Formerly smoked	639 (33.54)	53 (24.09)	586 (34.78)	
Never used	412 (21.63)	49 (22.27)	363 (21.54)	

Table 1 (*continued*)

Table 1 (*continued*)

Variables	Overall	Black race	White race	P value
Insurance[†]				<0.0001*
Medicaid	262 (7.82)	65 (15.93)	197 (6.70)	
Medicare	1,521 (45.42)	128 (31.37)	1,393 (47.36)	
Medicare/Medicaid	141 (4.21)	45 (11.03)	96 (3.26)	
Private	1,166 (34.82)	103 (25.25)	1,063 (36.14)	
Uninsured, self-pay	259 (7.73)	67 (16.42)	192 (6.53)	
Marital status at diagnosis[&]				<0.0001*
Divorced or separated	343 (10.27)	64 (15.76)	279 (9.51)	
Married	1,912 (57.26)	120 (29.56)	1,792 (61.10)	
Single	394 (11.80)	105 (25.86)	289 (9.85)	
Unknown	353 (10.57)	72 (17.73)	281 (9.58)	
Widowed	337 (10.09)	45 (11.08)	292 (9.96)	
Treatment[†]				
Surgery				<0.0001*
No	2,139 (63.87)	334 (81.86)	1,805 (61.37)	
Yes	1,210 (36.13)	74 (18.14)	1,136 (38.63)	
Radiation				<0.0001*
No	1,840 (54.94)	119 (29.17)	1,721 (58.52)	
Yes	1,509 (45.06)	289 (70.83)	1,220 (41.48)	
Systemic therapy				0.2291
No	1,869 (55.81)	239 (58.58)	1,630 (55.42)	
Yes	1,480 (44.19)	169 (41.42)	1,311 (44.58)	
Survival status[†]				0.0009*
Alive	920 (27.47)	84 (20.59)	836 (28.43)	
Dead	2,429 (72.53)	324 (79.41)	2,105 (71.57)	

Data are presented as n (%). [†], overall n=3,349, Black race n=408 (12.18%), White race n=2,941 (87.82%); [‡], overall n=3,347, Black race n=408 (12.19%)], White race n=2,939 (87.81%); [§], overall n=2,772, Black race n=358 (12.91%), White race n=2,414 (87.09%); [¶], overall n=1,905, Black race n=220 (11.55%), White race n=1,685 (88.45%); [&], overall n=3,339, Black race n=406 (12.16%), White race n=2,933 (87.84%). *, P value <0.05. NSCLC, non-small cell lung cancer.

of "contraindications due to other conditions" (OR: 2.606, 95% CI: 1.003–6.768) (*Table 4*).

Reasons that surgery was not performed for early-stage disease were explored by marital status as well. Multivariable analysis showed that, compared to married individuals, those who were widowed or single had greater odds of not receiving a recommended curative intent surgery due to "refusal by a patient or guardian" (OR: 4.711, 95% CI: 1.174–18.908 and OR: 5.697, 95% CI: 1.187–27.346, respectively). Compared to married individuals, those who were divorced had greater odds of not receiving curative intent surgery because it was not recommended due to a "contraindication based on other conditions" (OR: 2.293, 95% CI: 1.045–5.033) (*Table 4*). Black race compared to White race, was associated with greater odds of not receiving curative intent surgery for early-stage disease due

Table 2 Association of social determinants of health with advanced stage in patients with newly diagnosed NSCLC (multivariable logistic regression analysis)

Covariates	OR	95% CI for OR	P value
Gender			0.0004*
Male	1.460	1.183–1.801	0.0004*
Female	Reference	–	–
Cigarette use at time of diagnosis			0.1109
Currently smoked	1.189	0.898–1.575	0.2262
Formerly smoked	0.926	0.695–1.235	0.6025
Never used	Reference	–	–
Insurance			0.0177*
Medicaid	1.149	0.691–1.910	0.5921
Medicare	0.807	0.607–1.072	0.1392
Medicare/Medicaid	1.071	0.539–2.125	0.8454
Uninsured	1.710	1.119–2.612	0.0131*
Private	Reference	–	–
Marital status at diagnosis			0.1375
Divorced or separated	0.857	0.616–1.192	0.3586
Single	1.332	0.941–1.886	0.1062
Unknown	1.476	0.831–2.622	0.1843
Widowed	0.866	0.616–1.216	0.4062
Married	Reference	–	–
Age at diagnosis (years)	0.974	0.962–0.987	<0.0001*
Race			<0.0001*
Black	2.392	1.653–3.461	<0.0001*
White	Reference	–	–

*, P value <0.05. NSCLC, non-small cell lung cancer; OR, odds ratio; CI, confidence interval.

to surgery "not being a planned part of treatment," after adjusting for the other SDOH (OR: 1.779, 95% CI: 1.033–3.061) (*Table 4*). Those of older age were more likely to not receive curative intent surgery for early-stage disease for all the reasons listed in *Table 4*.

SDOH and receipt of radiation for early-stage NSCLC

Because radiation treatment can be an alternative treatment for some patients with early-stage NSCLC, especially those who are unable or unwilling to have a surgical procedure, we evaluated the impact of SDOH on receipt of radiation for early-stage NSCLC. On univariable analysis, receipt of radiation was significantly associated with insurance status, marital status, age, race, and cigarette use at the time of diagnosis (Table S5). On multivariable analysis, those currently smoking cigarettes at the time of NSCLC diagnosis had greater odds of receiving radiation therapy compared to those identified as never smoking cigarettes (OR: 2.329, 95% CI: 1.438–3.773, P=0.0006). Those uninsured had greater odds of receiving radiation for early-stage NSCLC compared to those who were privately insured (OR: 5.913, 95% CI: 2.647–13.209, P<0.0001), and older individuals were more likely to receive radiation for early-stage disease (OR: 1.042, 95% CI: 1.019–1.064, P=0.0002). Those who were widowed had greater odds

Table 3 Association of social determinants of health with the receipt of curative intent surgery for early-stage NSCLC (multivariable logistic regression analysis)

Covariates	OR	95% CI for OR	P value
Insurance (n=1,128)			<0.0001*
Medicaid (n=64)	0.332	0.172–0.639	0.0010*
Medicare (n=630)	0.661	0.443–0.987	0.0432*
Medicare/Medicaid (n=49)	0.549	0.274–1.103	0.0920
Uninsured (n=47)	0.211	0.105–0.425	<0.0001*
Private (n=338)	Reference	–	–
Marital status at diagnosis (n=1,123)			0.1654
Divorced or separated (n=116)	0.734	0.468–1.151	0.1775
Single (n=102)	0.850	0.525–1.377	0.5095
Unknown (n=92)	0.849	0.515–1.401	0.5220
Widowed (n=142)	0.621	0.418–0.923	0.0185*
Married (n=671)	Reference	–	–
Age at diagnosis (years) (n=1,130)	0.930	0.913–0.947	<0.0001*
Race (n=1,130)			0.0274*
Black (n=83)	0.562	0.337–0.938	0.0274*
White (n=1047)	Reference	–	–

*, P value <0.05. NSCLC, non-small cell lung cancer; OR, odds ratio; CI, confidence interval.

Table 4 Association of social determinants of health and reasons for not receiving curative intent surgery for early-stage NSCLC (multivariable logistic regression analysis)

Variables	N (%)	Odds ratio	95% CI	P value
Insurance (n=1,130)				0.0456*
Medicaid	66 (5.84)			
Surgery not a planned part of treatment	18 (27.27)	3.039	1.516–6.092	0.0017*
Surgery not recommended, contraindicated due to other condition	3 (4.55)	4.081	0.935–17.816	0.0615
Medicare	630 (55.75)			
Surgery not a planned part of treatment	194 (30.79)	1.291	0.835–1.995	0.2509
Surgery not recommended, contraindicated due to other condition	52 (8.25)	2.606	1.003–6.768	0.0492*
Surgery recommended; patient/guardian refused	10 (1.59)	1.630	0.175–15.156	0.6678
Surgery recommended, not performed; no reason recorded	11 (1.75)	3.452	0.369–32.315	0.2776
Unknown	3 (0.48)	2.269	0.126–40.718	0.5780
Medicare/Medicaid	49 (4.34)			
Surgery not a planned part of treatment	19 (38.78)	2.043	0.996–4.189	0.0512
Surgery recommended; patient/guardian refused	1 (2.04)	3.510	0.187–65.752	0.4009

Table 4 (*continued*)

Table 4 (*continued*)

Variables	N (%)	Odds ratio	95% CI	P value
Uninsured	47 (4.16)			
Surgery not a planned part of treatment	17 (36.17)	3.876	1.808–8.311	0.0005*
Surgery not recommended, contraindicated due to other condition	5 (10.64)	9.030	2.458–33.180	0.0009*
Surgery recommended; patient/guardian refused	1 (2.13)	8.069	0.452–143.944	0.1555
Surgery recommended, not performed; no reason recorded	2 (4.26)	20.723	1.724–249.038	0.0169*
Private (reference)	338 (29.91)	–	–	–
Marital status at diagnosis (n=1,123)				0.4081
Divorced or separated	116 (10.33)			
Surgery not a planned part of treatment	32 (27.59)	1.306	0.799–2.133	0.2868
Surgery not recommended, contraindicated due to other condition	10 (8.62)	2.293	1.045–5.033	0.0386*
Surgery recommended, not performed; no reason recorded	1 (0.86)	1.085	0.129–9.152	0.9400
Single	102 (9.08)			
Surgery not a planned part of treatment	25 (24.51)	1.099	0.645–1.873	0.7292
Surgery not recommended, contraindicated due to other condition	7 (6.86)	1.618	0.661–3.963	0.2924
Surgery recommended; patient/guardian refused	3 (2.94)	5.697	1.187–27.346	0.0297*
Unknown	92 (8.19)			
Surgery not a planned part of treatment	32 (34.78)	1.401	0.835–2.350	0.2015
Surgery not recommended, contraindicated due to other condition	2 (2.17)	0.466	0.106–2.051	0.3126
Surgery recommended; patient/guardian refused	1 (1.09)	1.644	0.168–16.063	0.6689
Widowed	142 (12.64)			
Surgery not a planned part of treatment	51 (35.92)	1.490	0.965–2.302	0.0721
Surgery not recommended, contraindicated due to other condition	14 (9.86)	1.711	0.846–3.463	0.1352
Surgery recommended; patient/guardian refused	5 (3.52)	4.711	1.174–18.908	0.0288*
Surgery recommended, not performed; no reason recorded	6 (4.23)	3.743	1.143–12.261	0.0292*
Married (reference)	671 (59.75)	–	–	–
Age at diagnosis (years) (n=1,130)				<0.0001*
Surgery not a planned part of treatment	293 (25.93)	1.076	1.054–1.097	<0.0001*
Surgery not recommended, contraindicated due to other condition	66 (5.84)	1.079	1.041–1.118	<0.0001*
Surgery recommended; patient/guardian refused	13 (1.15)	1.109	1.026–1.198	0.0094*
Surgery recommended, not performed; no reason recorded	14 (1.24)	1.055	0.981–1.135	0.1508
Unknown	4 (0.35)	1.021	0.882–1.182	0.7783

Table 4 (*continued*)

Table 4 (*continued*)

Variables	N (%)	Odds ratio	95% CI	P value
Race (n=1,130)				0.0793
Black	83 (7.35)			
Surgery not a planned part of treatment	31 (37.35)	1.779	1.033–3.061	0.0377*
Surgery not recommended, contraindicated due to other condition	4 (4.82)	1.274	0.420–3.860	0.6687
Surgery recommended; patient/guardian refused	1 (1.20)	1.328	0.154–11.488	0.7965
Surgery recommended, not performed; no reason recorded	2 (2.41)	3.681	0.748–18.118	0.1090
Unknown	1 (1.20)	13.208	1.275–136.789	0.0305*
White (reference)	1,047 (92.65)	–	–	–

Possible reasons for not receiving surgery include, "surgery not a planned part of treatment", "surgery not recommended, contraindicated due to other condition", "surgery recommended; patient/guardian refused", "surgery recommended, not performed; no reason recorded", and "unknown". Within each variable, only recorded reasons for not receiving surgery are included. *, P value <0.05. NSCLC, non-small cell lung cancer; CI, confidence interval.

of receiving radiation compared to married individuals (OR: 1.631, 95% CI: 1.021–2.604, P=0.0406). There was no significant difference in the odds of receiving radiation in early-stage NSCLC among Black and White patients (*Table 5*).

SDOH and receipt of stage appropriate treatment for advanced-stage NSCLC

In those with advanced-stage NSCLC, insurance status, marital status, age, and race were all associated with lower odds of receiving stage appropriate systemic therapy by univariable analysis (all P<0.0001) (Table S6). On multivariable analysis, those significantly less likely to receive stage-appropriate therapy for advanced disease were uninsured (OR: 0.411, 95% CI: 0.284–0.592, P<0.0001), had combined Medicare/Medicaid (OR: 0.423, 95% CI: 0.247–0.726, P=0.0018), were single (OR: 0.509, 95% CI: 0.371–0.698, P<0.0001), widowed (OR: 0.519, 95% CI: 0.358–0.752, P=0.0005), and Black (OR: 0.668, 95% CI: 0.503–0.887, P=0.0053) (*Table 6*).

SDOH and time to treatment

The median time from diagnosis to the first treatment was 0.9 months for both Black and White individuals (95% CI: 0.7–1.0 and 0.8–0.9, respectively) (Figure S1). By univariable Cox proportional hazard regression, SDOH which included cigarette use at diagnosis, insurance status, marital status, race, stage, and age were significantly associated with greater time from diagnosis to treatment (Table S7). By multivariable analysis, individuals who currently smoked [hazard ratio (HR): 2.440, 95% CI: 2.004–2.971, P<0.0001] and formerly smoked (HR: 5.218, 95% CI: 4.039–6.742, P<0.0001) had and increased time to treatment compared to never smokers. Those with any insurance type other than private insurance had an increased time to treatment [P<0.0001 (Medicare, Medicare/Medicaid, uninsured), P=0.0201 (Medicaid)]. Those widowed (HR: 2.109, 95% CI: 1.646–2.702, P<0.0001) had a greater time to treatment onset compared to the reference married status. Those with advanced stage had a greater time to treatment onset compared to early stage (HR: 12.738, 95% CI: 10.076–16.102, P<0.0001) (Table S8).

Impact of race, gender, insurance, and marital status, and stage on 5-year OS

In this NSCLC cohort, survival varied significantly by advancing stage and by race, with worse 5-year OS in Black compared to White race individuals (HR: 1.41, 95% CI: 1.25–1.60, P<0.0001) (*Figure 1A*). Survival was further delineated based on insurance type. Compared to individuals with private insurance, lower 5-year OS was associated with being uninsured (HR: 1.79, 95% CI: 1.52–2.11), having combined Medicaid/Medicare insurance (HR: 1.32, 95% CI: 1.05–1.65), having Medicare only insurance (HR: 1.13, 95% CI: 1.02–1.25), and having Medicaid only insurance (HR: 1.25, 95% CI: 1.05–1.49, P<0.0001) compared to private insurance (*Figure 1B*). Male

Table 5 Association of social determinants of health with the receipt of radiation therapy for early-stage NSCLC (multivariable logistic regression analysis)

Covariates	OR	95% CI for OR	P value
Cigarette use at time of diagnosis (n=697)			0.0021*
Currently smokes (n=264)	2.329	1.438–3.773	0.0006*
Formerly smoked (n=292)	1.559	0.965–2.518	0.0694
Never used (n=141)	Reference	–	–
Insurance (n=1,130)			0.0003*
Medicaid (n=66)	2.397	0.970–5.924	0.0583
Medicare (n=630)	1.174	0.736–1.873	0.5002
Medicare/Medicaid (n=49)	1.462	0.452–4.734	0.5260
Uninsured (n=47)	5.913	2.647–13.209	<0.0001*
Private (n=338)	Reference	–	–
Marital status at diagnosis (n=1,123)			0.0736
Divorced or separated (n=116)	0.859	0.499–1.478	0.5830
Single (n=102)	1.793	0.987–3.257	0.0553
Unknown (n=92)	0.901	0.318–2.554	0.8442
Widowed (n=142)	1.631	1.021–2.604	0.0406*
Married (n=671)	Reference	–	–
Age at diagnosis (years) (n=1,130)	1.042	1.019–1.064	0.0002*
Race (n=1,130)			0.1070
Black (n=83)	1.758	0.885–3.492	0.1070
White (n=1,047)	Reference	–	–

Included variables are those deemed significant in univariable analysis (cigarette use at time of diagnosis, insurance, marital status, age at diagnosis, and race). *, P value <0.05. NSCLC, non-small cell lung cancer; OR, odds ratio; CI, confidence interval.

gender compared to female gender was also associated with worse 5-year OS (HR: 1.29, 95% CI: 1.18–1.41, P<0.0001) (*Figure 1C*). When stratified by marital status, worse 5-year OS was observed in those who were single (HR: 1.44, 95% CI: 1.26–1.65), widowed (HR: 1.19, 95% CI: 1.03–1.38), or had an unknown marital status (HR: 1.35, 95% CI: 1.15–1.57, P<0.0001) when compared to married individuals (*Figure 1D*).

On multivariable analysis controlled for SDOH, Black race itself was not associated with worse OS time in this cohort (Table S9). An increased HR for death was seen in those with Medicare, combined Medicare/Medicaid, and uninsured status (HR: 1.970, 1.756, and 2.658 respectively), and advanced stage at diagnosis (HR: 1.672, 95% CI: 1.446–1.934) (Table S9). As expected, OS and 5-year OS decreased with advancing stage at the time of diagnosis (Figure S2), and there was no statistically significant racial difference in 5-year OS based on individual stage (Figure S3).

Discussion

Key findings

Over the last 5 years, lung cancer mortality has declined among U.S. adults, due to increased screening efforts and tobacco cessation strategies (1). However, racial disparities persist as Black individuals are more likely to be diagnosed with advanced-stage disease and have worse survival compared to other U.S. racial/ethnic groups (1,30,31). Here we demonstrate that in those with newly diagnosed NSCLC, individual SDOH matter and influence stage at diagnosis, receipt of stage appropriate treatment, timing

Table 6 Association of social determinants of health with the receipt of systemic therapy for advanced stage NSCLC (multivariable logistic regression analysis)

Covariates	Odds ratio	95% CI for OR	P value
Insurance (n=1,642)			<0.0001*
Medicaid (n=165)	0.774	0.528–1.135	0.1901
Medicare (n=638)	0.846	0.627–1.143	0.2764
Medicare/Medicaid (n=71)	0.423	0.247–0.726	0.0018*
Uninsured (n=169)	0.411	0.284–0.592	<0.0001*
Private (n=599)	Reference	–	–
Marital status at diagnosis (n=1,639)			<0.0001*
Divorced or separated (n=178)	0.837	0.591–1.185	0.3153
Single (n=234)	0.509	0.371–0.698	<0.0001*
Unknown (n=151)	0.765	0.528–1.109	0.1573
Widowed (n=146)	0.519	0.358–0.752	0.0005*
Married (n=930)	Reference	–	–
Age at diagnosis (years) (n=1,642)	0.971	0.959–0.984	<0.0001*
Race (n=1,642)			0.0053*
Black (n=275)	0.668	0.503–0.887	0.0053*
White (n=1,367)	Reference	–	–

*, P value <0.05. Included variables are those deemed significant in univariable analysis (insurance, marital status, age at diagnosis, and race). NSCLC, non-small cell lung cancer; OR, odds ratio; CI, confidence interval.

of treatment initiation, reasons individuals do not receive guideline concordant lung cancer treatment, and 5-year OS.

Explanation of findings and comparison to similar studies

As diagnosis of NSCLC at advanced stage is associated with decreased survival, we similarly observed this in our cohort of patients with newly diagnosed NSCLC. We further studied those individual level SDOH associated with advanced stage at diagnosis. Inadequate health insurance is one of the largest barriers to healthcare access and the unequal distribution of coverage contributes to other observed health disparities (32,33). In this cohort, those who were uninsured were more likely to be diagnosed with advanced-stage NSCLC compared to those with private insurance. Marital status is a surrogate for social support, with some studies suggesting that social support from interactions with family may help reduce the negative impact of discrimination and financial hardships on health and well-being (34). We found a greater percentage of single individuals were diagnosed with advanced-stage disease compared to those who were married at the time of diagnosis. However, multivariable analysis associated only male gender, uninsured status, age, and Black race as independent predictors of advanced stage at diagnosis, suggesting that increased diagnosis of advanced-stage NSCLC in single persons may be impacted by these SDOH.

Consistent with other studies, we found evidence for racial disparities in NSCLC OS. In this cohort, Black race was associated with worse 5-year OS compared to White race. However, when adjusted for the individual level SDOH (race, gender, insurance, and marital status) and clinical diagnosis stage, we found worse 5-year OS was not significantly associated with race alone but rather with insurance and marital status. Specifically, those with Medicare only, combined Medicaid/Medicare, and uninsured had worse OS compared to those with private only insurance. Similarly, the Southern Community Cohort study suggested worse survival in Black patients. However, when adjusted for socioeconomic status (SES) and cancer stage at diagnosis (with more advanced-stage lung cancer

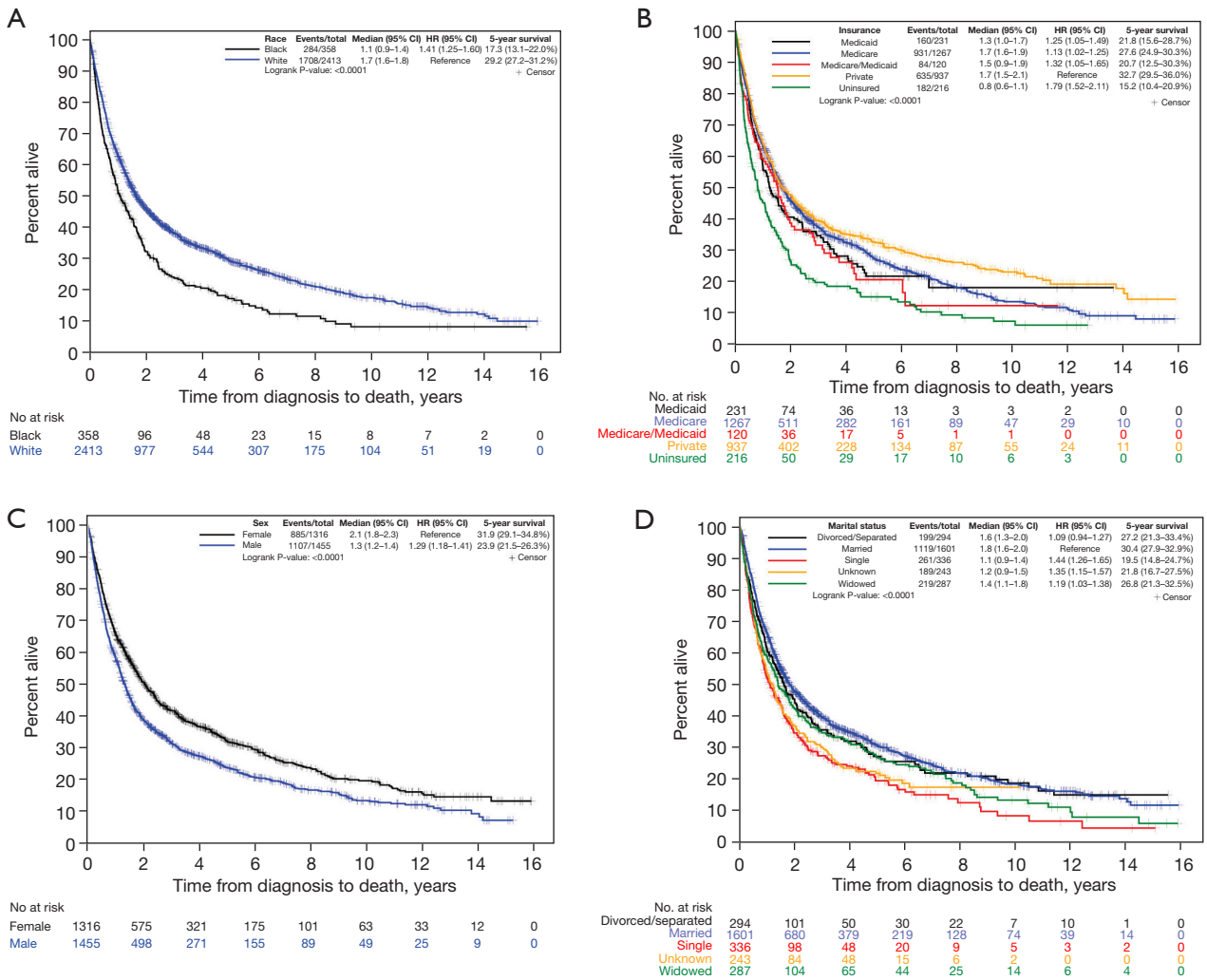

Figure 1 Kaplan-Meier estimates of 5-year overall survival based on race (A), insurance type (B), gender (C), and marital status (D). HR, hazard ratio; CI, confidence interval.

in Black patients), they also found that mortality was similar between the two races, suggesting that differences in survival may be due to social and economic disparities in Black communities (35). Further support comes from a large database of Floridians with NSCLC in which those living in neighborhoods of low socioeconomic state had lower survival compared to those in high socioeconomic neighborhoods (36). That study used U.S. Census data to assess neighborhood level determinants of health. However, unlike our cohort, they were unable to assess survival differences based on individual-level SES or SDOH nor determine which SES or SDOH were predictors of worse survival.

We found convincing evidence suggesting that racial differences in survival were strongly influenced by differing SDOH that disproportionately affect Black individuals, particularly insurance and marital status. We then investigated how these individual SDOH impacted the receipt of evidence-based guidelines for NSCLC treatment. For advanced-stage disease, those uninsured or having combined Medicare/Medicaid insurance, single, widowed, and Black were less likely to receive guideline concordant treatment, which each represent vulnerable populations. For those with early-stage NSCLC, age, insurance status other than private insurance (uninsured, Medicaid, Medicare), being widowed, and Black race influenced the receipt of stage-appropriate, curative intent surgery. This highlights differing NSCLC treatment among vulnerable groups

based on individual SDOH and regardless of lung cancer stage. Regardless of insurance status, Black individuals were found to be almost half as likely as White individuals to receive guideline-concordant surgical resection for early-stage disease. This suggests that there are discriminating factors other than insurance status that influence the receipt of surgery for early-stage NSCLC. We also found a greater percentage of single and widowed early-stage NSCLC patients were less likely to receive curative intent surgery compared to married individuals, which may speak to the impact of social support on early lung cancer treatment.

Chen *et al.* found that unmarried patients were less likely to receive definite treatment in several cancers, including lung cancer (37). Reasons postulated for this include lower adherence to prescribed treatments among unmarried persons, lack of social support, and low tolerance for aggressive treatments. Based on these postulated, but untested, rationales physicians may be inclined to not offer such treatments. However, a study by Aizer *et al.* using the SEER database to study the impact of marital status and cancer therapy found that only 0.52% of unmarried patients with cancer declined physician recommended surgery (38). This suggests that unmarried NSCLC patients may simply not be offered surgery. We found that the reasons for not receiving surgery likely vary by specific social circumstances. For instance, we found that widowed and single individuals were more likely to refuse recommended surgical resection, which may suggest these two groups may benefit from additional support from providers when it comes to discussing lung cancer treatment options to ensure that they feel supported in their treatment decisions. Reasons for variability in these therapeutic decisions based on marital status should be further explored to ensure equitable access to best care in early-stage NSCLC.

We also found that uninsured persons were nearly 80% less likely to receive curative intent surgery for early-stage NSCLC compared to those with private insurance. Uninsured NSCLC patients were almost four times more likely to not even be offered surgery as a part of the treatment plan and nine times more likely to not be recommended curative intent surgery because of "contraindications due to other condition", which may speak to treatment disparities based on insurance status and worse overall health among this group increasing one's surgical risk. In the U.S., Medicaid status is a surrogate for individual poverty level, while Medicare status is in part considered a function of age, which plays a seminal role in one's overall health and survival. For Indiana residents, Medicaid covers oncology services, including cancer prevention, diagnosis, therapeutic treatment, rehabilitation, and palliative care. We found those with Medicaid insurance were 67% less likely to receive curative intent surgery for early-stage NSCLC compared to privately insured individuals. While Medicare insurance typically includes those 65 years of age and older, and presumably those with worse overall health as a function of increased age, this group was only 34% less likely than privately insured individuals to receive curative intent surgery. This suggests that poverty is likely a driver behind observed disparities in early NSCLC treatment.

When it comes to race, we found Black individuals were 1.8 times less likely to receive curative intent surgery because it was "not part of the recommended treatment plan". This suggests underlying reasons for physician bias in lung cancer treatment that should be further explored to ensure equitable care for all regardless of race. Additionally, these disparate findings represent a rationale for careful assessment of patients who are not offered or refuse standard of care surgery and provide a possible framework by which physicians can provide tailored support to patients to avoid treatment bias based on SDOH. For instance, a study by Camposilvan *et al.* suggested that surgeon total NSCLC procedural volume influences decisions surrounding procedural selection, which may impact the delivery of cancer care for such patients (39). Given the retrospective nature of this study, we were unable to analyze specific surgical patterns or robustness of our cardiothoracic program at the time. However, the findings of this study will frame the foundation of prospective studies designed to further assess specific reasons for varying surgical practices associated with various SDOH (31).

Implications and actions needed

While race and gender are non-modifiable SDOH, provider recognition of the impact of one's race on their lived experiences and distribution of resources influencing their access to equitable medical care is one that can be modified. Additionally, provider attitudes, behaviors, and shared decision making when discussing lung cancer screening and cancer treatment options may be an area of improvement. Individual SDOH like insurance type can be modified in hopes of improving lung cancer outcomes that we have shown to be affected by insurance type. Our study found an association between SDOH (male gender, Black race, insurance status) and advanced stage at diagnosis,

which suggest these could represent risk factors for the development of lung cancer which could be considered in determining eligibility for lung cancer screening and early detection. Our findings suggest that even if lung cancer screening with low-dose CT chest was provided to all eligible individuals based on our current screening guidelines, it would not benefit many patients with early-stage disease that are not offered surgical resection with curative intent based on their insurance status or race.

Our study also suggests a possibility of provider implicit bias when it comes to stereotypes surrounding patient treatment preferences, refusal of provider recommendations, and social support. More work needs to be done including prospective studies to understand discrepancies in guideline concordant treatment for NSCLC in vulnerable populations. Further characterization of individual social needs that may be barriers to lung cancer care (i.e., transportation, social support, insurance) should be done to mitigate any such barriers. Current work is being done to identify screening eligibility criteria in addition to 20+ pack-years smoking history and 15 years since quitting, that could better identify those at highest risk for the development of lung cancer. Particularly, Kondo *et al.* suggest lung cancer risk not only persist past the 15 year since quitting criteria in current screening guidelines, but that it may remain increased for 2–3 decades (40). The Sybil model, a radiology-based learning model, has also been shown to predict future lung cancer risk, suggesting that artificial intelligence (AI) could be used in the future to identify people at the highest risk for the development of lung cancer, regardless of smoking history (41). Prospective studies including diverse patient populations are needed to assess how individual SDOH, including insurance and marital status, can be combined with AI, and our current screening guidelines to better identify those at increased risk for lung cancer. Therefore, targeted screening efforts in vulnerable populations could be employed to reduce advanced stage at diagnosis based on those with the highest risk.

Strengths and limitations

One of the advantages of our study is that it was conducted at IUSCCC, the only National Cancer Institute-designated comprehensive cancer center in Indiana. Another strength of this study is the ability to assess individual level SDOH and their effect on staging, 5-year OS, receipt of stage appropriate treatment, and specific reasons for variation from standard of care treatment in early-stage NSCLC. Our study provides a comprehensive evaluation of these specific SDOH (race, gender, marital status, insurance status) on reasons for not receiving recommended treatment for early-stage NSCLC, which is novel. This knowledge will inform future prospective studies to directly explore reasons for the observed disparities in guideline concordant treatment of early-stage disease based on these SDOH.

There are limitations to this study. First, this is single center study retrospective analysis conducted at a Midwest academic medical center and cancer center, which may not reflect lung cancer disparities observed in other geographic areas. Other important SDOH, such as income and education levels, were not included in this database, hence we could not study the effect of these on our primary and secondary outcomes. We found treatment discordance in advanced-stage disease that was associated by race and SDOH; unfortunately, reasons for differential receipt of chemotherapy and radiation were not collected in this registry. Further, this database cannot differentiate SBRT from conventional radiation when listing "radiation" as a treatment type for early-stage NSCLC. An additional limitation of this retrospective study is the database did not include co-morbidities for patients. While we recognize that co-morbidities may account for reasons potentially curative surgery was not provided for patients diagnosed with early-stage disease, it does not entirely explain the above disparities in early-stage disease associated with race, marital status, and insurance. OS was analyzed as opposed to lung cancer-specific survival as cause of death was not included in this database. However, important outcomes of interest were observed differences in stage-specific NSCLC treatment and particularly reasons for not receiving curative intent surgery for early-stage disease, controlling for individual SDOH.

Another limitation of this study is that other patient characteristics such as education, body mass index (BMI), performance status, Charlson comorbidity index (CCI), and limited forced expiratory volume in one second (FEV1) were not available in our registry. While these factors may impact reasons for not offering surgery to certain patients with early-stage NSCLC, it would not fully explain observed differences based on race and insurance status.

The retrospective cohort included those with newly diagnosed NSCLC between January 1, 2000 and May 31, 2015, and individual staging was determined based on the contemporary AJCC staging (editions 5, 6, and 7). A retrospective study by Erdoğu *et al.* showed upstaging when

evaluating the effects of transitioning from the 6th to the 7th staging systems; however, this only included those who received surgery and therefore was insufficient to compare survival curves in those diagnosed with advanced stage that did not receive surgery, which included the larger portion of our cohort, particularly Black individuals (42). As stage at the time of diagnosis was used to determine treatment decisions, we felt that re-staging based on a single AJCC edition would introduce bias to this important endpoint.

Conclusions

Our study supports the hypothesis that SDOH impact stage appropriate treatment and survival for NSCLC patients, particularly in those with early-stage NSCLC. While race has been described as a social construct and identified as a risk factor for lung cancer incidence and survival, it is also highly linked to differing SDOH, which often disproportionately render Black individuals with worse health outcomes.

Factors associated with NSCLC patients of Black race, including gender, insurance status, and marital status, contribute to access to quality care, environmental exposures, social support, and differences in medical decision-making that may impact diagnosis, lung cancer care, and outcomes. Our study suggests some individual-level SDOH disproportionately affect Black individuals resulting in poor NSCLC outcomes. It also suggests that implicit bias may impact patient and physician practices pertaining to interventions such as receipt of potentially curative surgery for early-stage NSCLC. Understanding and addressing these risk factors may help to mitigate racial lung cancer disparities. More studies are needed to evaluate the impact of these and other factors on racial disparities in lung cancer development and outcomes, and to further define these risks, which may improve efforts for early identification and improved treatment outcomes in all patients with NSCLC.

Acknowledgments

We would like to thank Sylk Sotto, EDD, MPS, MBA for her constructive review of this manuscript.

Funding: This research was funded in part by the American Cancer Society (Grant No. 128511-MRSG-15-163-01-DMC) and the U.S. Department of Veterans Affairs BLR&D, Merit Review (Grant No. I01-BX005353 to C.R.S.). Additional funding sources were in the form of training grants from the National Institutes of Health to Indiana University School of Medicine to F.C.D. (Nos. TL1 TR002531 and 5R25-HL126140-08 PRIDE-AiRE) and to N.A.N. (No. T32HL091816). The contents of this manuscript do not necessarily represent the views of the U.S. Department of Veterans Affairs or the United States Government.

Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://tlcr.amegroups.com/article/view/10.21037/tlcr-23-407/rc

Data Sharing Statement: Available at https://tlcr.amegroups.com/article/view/10.21037/tlcr-23-407/dss

Peer Review File: Available at https://tlcr.amegroups.com/article/view/10.21037/tlcr-23-407/prf

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://tlcr.amegroups.com/article/view/10.21037/tlcr-23-407/coif). F.C.D. reports this research was funded in part by training grants from the NIH-NRSA (No. TL1 TR002531) and NIH-NHLBI (No. 5R25-HL126140-08 PRIDE-AiRE). N.A.N. reports funding to Indiana University School of Medicine in the form of a training grant (NIH-NHLBI, No. T32HL091816). L.N. has a research grant from Delfi Diagnostics. They paid the grant directly to his institution. C.R.S. reports this research was funded in part by the American Cancer Society (Grant No. 128511-MRSG-15-163-01-DMC) and the U.S. Department of Veterans Affairs BLR&D, Merit Review (Grant No. I01-BX005353). She provides unpaid service related to lung cancer screening for National Comprehensive Cancer Network (NCCN, Lung Cancer Screening Guidelines panel) that is not directly related to the research performed in this manuscript. The other authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Indiana University School of Medicine Institutional Review Board (IRB# 16613) and individual consent for this retrospective

analysis was waived.

References

1. Siegel RL, Miller KD, Fuchs HE, et al. Cancer statistics, 2022. CA Cancer J Clin 2022;72:7-33.
2. Schabath MB, Cress D, Munoz-Antonia T. Racial and Ethnic Differences in the Epidemiology and Genomics of Lung Cancer. Cancer Control 2016;23:338-46.
3. Potter AL, Rosenstein AL, Kiang MV, et al. Association of computed tomography screening with lung cancer stage shift and survival in the United States: quasi-experimental study. BMJ 2022;376:e069008.
4. Rivera MP, Katki HA, Tanner NT, et al. Addressing Disparities in Lung Cancer Screening Eligibility and Healthcare Access. An Official American Thoracic Society Statement. Am J Respir Crit Care Med 2020;202:e95-e112.
5. Namburi N, Timsina L, Ninad N, et al. The impact of social determinants of health on management of stage I non-small cell lung cancer. Am J Surg 2022;223:1063-6.
6. Haddad DN, Sandler KL, Henderson LM, et al. Disparities in Lung Cancer Screening: A Review. Ann Am Thorac Soc 2020;17:399-405.
7. Hacker K, Auerbach J, Ikeda R, et al. Social Determinants of Health-An Approach Taken at CDC. J Public Health Manag Pract 2022;28:589-94.
8. Dihwa V, Shadowen H, Barnes AJ. Medicaid can and should play an active role in advancing health equity. Health Serv Res 2022;57 Suppl 2:167-71.
9. Bradley CJ, Dahman B, Given CW. Treatment and survival differences in older Medicare patients with lung cancer as compared with those who are dually eligible for Medicare and Medicaid. J Clin Oncol 2008;26:5067-73.
10. Whitson BA, Groth SS, Duval SJ, et al. Surgery for early-stage non-small cell lung cancer: a systematic review of the video-assisted thoracoscopic surgery versus thoracotomy approaches to lobectomy. Ann Thorac Surg 2008;86:2008-16; discussion 2016-8.
11. Moghanaki D, Chang JY. Is surgery still the optimal treatment for stage I non-small cell lung cancer? Transl Lung Cancer Res 2016;5:183-9.
12. Moghanaki D, Karas T, Timmerman RD, et al. Protocol for the Veterans Affairs Cooperative Studies Program Study Number 2005. CHEST Pulmonary 2023;1:100024.
13. Esnaola NF, Gebregziabher M, Knott K, et al. Underuse of surgical resection for localized, non-small cell lung cancer among whites and African Americans in South Carolina. Ann Thorac Surg 2008;86:220-6; discussion 227.
14. Yorio JT, Yan J, Xie Y, et al. Socioeconomic disparities in lung cancer treatment and outcomes persist within a single academic medical center. Clin Lung Cancer 2012;13:448-57.
15. Sears CR, Rivera MP. Age, Sex, Smoking, and Race: Is Progress Being Made in Lung Cancer Screening Eligibility? Chest 2021;160:31-3.
16. Haiman CA, Stram DO, Wilkens LR, et al. Ethnic and racial differences in the smoking-related risk of lung cancer. N Engl J Med 2006;354:333-42.
17. Araujo SEA, Leal A, Centrone AFY, et al. Impact of COVID-19 pandemic on care of oncological patients: experience of a cancer center in a Latin American pandemic epicenter. Einstein (Sao Paulo) 2020;19:eAO6282.
18. Rucinska M, Nawrocki S. COVID-19 Pandemic: Impact on Cancer Patients. Int J Environ Res Public Health 2022;19:12470.
19. Richards M, Anderson M, Carter P, et al. The impact of the COVID-19 pandemic on cancer care. Nat Cancer 2020;1:565-7.
20. Reyes R, Lopez-Castro R, Auclin E, et al. MA03.08 Impact of COVID-19 Pandemic in the Diagnosis and Prognosis of Lung Cancer. J Thorac Oncol 2021;16:S141.
21. Cantini L, Mentrasti G, Russo GL, et al. Evaluation of COVID-19 impact on DELAYing diagnostic-therapeutic pathways of lung cancer patients in Italy (COVID-DELAY study): fewer cases and higher stages from a real-world scenario. ESMO Open 2022;7:100406.
22. Nephew LD, Aitcheson G, Iyengar M. The Impact of Racial Disparities on Liver Disease Access and Outcomes. Curr Treat Options Gastro 2022;20:279-94.
23. Shi L, Stevens GD. Vulnerability and unmet health care needs. The influence of multiple risk factors. J Gen Intern Med 2005;20:148-54.
24. Hines RB, Zhu X, Lee E, et al. Health insurance and neighborhood poverty as mediators of racial disparities in advanced disease stage at diagnosis and nonreceipt

of surgery for women with breast cancer. Cancer Med 2023;12:15414-23.
25. Wadhera RK, Wang Y, Figueroa JF, et al. Mortality and Hospitalizations for Dually Enrolled and Nondually Enrolled Medicare Beneficiaries Aged 65 Years or Older, 2004 to 2017. JAMA 2020;323:961-9.
26. Bahiru E, Ziaeian B, Moucheraud C, et al. Association of Dual Eligibility for Medicare and Medicaid With Heart Failure Quality and Outcomes Among Get With The Guidelines-Heart Failure Hospitals. JAMA Cardiol 2021;6:791-800.
27. Edge SB, Compton CC. The American Joint Committee on Cancer: the 7th edition of the AJCC cancer staging manual and the future of TNM. Ann Surg Oncol 2010;17:1471-4.
28. Greene FL, Page DL, Fleming ID, et al. AJCC cancer staging manual, 6th ed. New York: Springer; 2002.
29. Fleming ID, Cooper JS, Henson DE, et al. AJCC Cancer Staging Manual, 5th ed. New York: Lippencott-Raven; 1997.
30. Soneji S, Tanner NT, Silvestri GA, et al. Racial and Ethnic Disparities in Early-Stage Lung Cancer Survival. Chest 2017;152:587-97.
31. Annangi S, Nutalapati S, Foreman MG, et al. Potential Racial Disparities Using Current Lung Cancer Screening Guidelines. J Racial Ethn Health Disparities 2019;6:22-6.
32. Call KT, McAlpine DD, Garcia CM, et al. Barriers to care in an ethnically diverse publicly insured population: is health care reform enough? Med Care 2014;52:720-7.
33. Sohn H. Racial and Ethnic Disparities in Health Insurance Coverage: Dynamics of Gaining and Losing Coverage over the Life-Course. Popul Res Policy Rev 2017;36:181-201.
34. Robards J, Evandrou M, Falkingham J, et al. Marital status, health and mortality. Maturitas 2012;73:295-9.
35. Aldrich MC, Grogan EL, Munro HM, et al. Stage-adjusted lung cancer survival does not differ between low-income Blacks and Whites. J Thorac Oncol 2013;8:1248-54.
36. Tannenbaum SL, Koru-Sengul T, Zhao W, et al. Survival disparities in non-small cell lung cancer by race, ethnicity, and socioeconomic status. Cancer J 2014;20:237-45.
37. Chen ZH, Yang KB, Zhang YZ, et al. Assessment of Modifiable Factors for the Association of Marital Status With Cancer-Specific Survival. JAMA Netw Open 2021;4:e2111813.
38. Aizer AA, Chen MH, Parekh A, et al. Refusal of curative radiation therapy and surgery among patients with cancer. Int J Radiat Oncol Biol Phys 2014;89:756-64.
39. Camposilvan I, Akhtar-Danesh N, Schneider L, et al. The effect of surgeon volume on procedure selection in non-small cell lung cancer surgeries. J Thorac Cardiovasc Surg 2015;150:507-12.
40. Kondo KK, Rahman B, Ayers CK, et al. Lung cancer diagnosis and mortality beyond 15 years since quit in individuals with a 20+ pack-year history: A systematic review. CA Cancer J Clin 2024;74:84-114.
41. Osarogiagbon RU, Yang PC, Sequist LV. Expanding the Reach and Grasp of Lung Cancer Screening. Am Soc Clin Oncol Educ Book 2023;43:e389958.
42. Erdoğu V, Çıtak N, Sezen CB, et al. Comparison of 6th, 7th, and 8th editions of the TNM staging in non-small cell lung cancer patients: Validation of the 8th edition of TNM staging. Turk Gogus Kalp Damar Cerrahisi Derg 2022;30:395-403.

Cite this article as: Duncan FC, Al Nasrallah N, Nephew L, Han Y, Killion A, Liu H, Al-Hader A, Sears CR. Racial disparities in staging, treatment, and mortality in non-small cell lung cancer. Transl Lung Cancer Res 2024;13(1):76-94. doi: 10.21037/tlcr-23-407

Supplementary

Table S1 Comparison of baseline characteristics based on stage at diagnosis

Variables	Subcategories	Stage at diagnosis			P value
		Overall (n=2,772)	Early stage (n=1,130, 40.76%)	Advanced stage (n=1,642, 59.24%)	
Gender	Female	1317 (47.51)	593 (45.03)	724 (54.97)	<0.0001*
	Male	1455 (52.49)	537 (36.91)	918 (63.09)	
Cigarette use at time of diagnosis (n=1,669)	Currently smoked	750 (44.94)	264 (35.20)	486 (64.80)	<0.0001*
	Formerly smoked	591 (35.41)	292 (49.41)	299 (50.59)	
	Never used	328 (19.65)	141 (42.99)	187 (57.01)	
Insurance	Medicaid	231 (8.33)	66 (28.57)	165 (71.43)	<0.0001*
	Medicare	1268 (45.74)	630 (49.68)	638 (50.32)	
	Medicare/Medicaid	120 (4.33)	49 (40.83)	71 (59.17)	
	Private	937 (33.80)	338 (36.07)	599 (63.93)	
	Uninsured, self-pay	216 (7.79)	47 (21.76)	169 (78.24)	
Marital status at diagnosis (n=2,519)	Divorced or separated	294 (11.67)	116 (39.46)	178 (60.54)	<0.0001*
	Married	1601 (63.56)	671 (41.91)	930 (58.09)	
	Single	336 (13.34)	102 (30.36)	234 (69.64)	
	Widowed	288 (11.43)	142 (49.31)	146 (50.69)	
Age at diagnosis (years)	–	63.42±11.23	66.00±10.65	61.64±11.27	<0.0001*
Race	Black	358 (12.91)	83 (23.18)	275 (76.82)	<0.0001*
	White	2414 (87.09)	1047 (43.37)	1367 (56.63)	

Data are presented as n (%) or mean ± standard deviation. For categories with missing values, overall patient number (n) is provided. P value comparisons across stage at diagnosis categories are based on Chi-square test of homogeneity for categorical variables; P values for continuous variables are based on the Wilcoxon Rank Sum Test. *, P value <0.05.

https://dx.doi.org/10.21037/tlcr-23-407

Table S2 Association of social determinants of health with advanced stage in patients with newly diagnosed non-small cell lung cancer (univariable logistic regression analysis)

Covariate	OR	95% CI for OR	P value
Gender			<0.0001*
Male	1.400	1.203–1.630	<0.0001*
Female	Reference	–	–
Cigarette use at time of diagnosis			<0.0001*
Currently smoked	1.388	1.065–1.809	0.0153*
Formerly smoked	0.772	0.588–1.013	0.0620
Never used	Reference	–	–
Insurance			<0.0001*
Medicaid	1.411	1.029–1.933	0.0323*
Medicare	0.571	0.481–0.679	<0.0001*
Medicare/Medicaid	0.818	0.555–1.205	0.3087
Uninsured	2.029	1.430–2.878	<0.0001*
Private	Reference	–	–
Marital status at diagnosis			<0.0001*
Divorced or separated	1.107	0.859–1.427	0.4324
Single	1.655	1.285–2.131	<0.0001*
Unknown	1.184	0.897–1.563	0.2325
Widowed	0.742	0.577–0.954	0.0199*
Married	Reference	–	–
Age at diagnosis (years)	0.964	0.957–0.971	<0.0001*
Race			<0.0001*
Black	2.538	1.960–3.286	<0.0001*
White	Reference	–	–

*, P value <0.05. OR, odds ratio; CI, confidence interval.

https://dx.doi.org/10.21037/tlcr-23-407

Table S3 Comparison of social determinants of health based on the receipt of curative intent surgery for early-stage non-small cell lung cancer (column percentage)

Variables	Receive surgery for early-stage disease?			P value
	Overall (n=1,130)	No (n=392, 34.69%)	Yes (n=738, 65.31%)	
Gender				0.6808
Female	593 (52.48)	209 (53.32)	384 (52.03)	
Male	537 (47.52)	183 (46.68)	354 (47.97)	
Cigarette use at time of diagnosis (n=697)				0.2796
Currently smoked	264 (37.88)	94 (38.84)	170 (37.36)	
Formerly smoked	292 (41.89)	107 (44.21)	185 (40.66)	
Never used	141 (20.23)	41 (16.94)	100 (21.98)	
Insurance				<0.0001*
Medicaid	66 (5.84)	21 (5.36)	45 (6.10)	
Medicare	630 (55.75)	272 (69.39)	358 (48.51)	
Medicare/Medicaid	49 (4.34)	20 (5.10)	29 (3.93)	
Private	338 (29.91)	54 (13.78)	284 (38.48)	
Uninsured	47 (4.16)	25 (6.38)	22 (2.98)	
Marital status at diagnosis (n=1,123)				<0.0001*
Divorced or separated	116 (10.33)	43 (11.05)	73 (9.95)	
Married	671 (59.75)	200 (51.41)	471 (64.17)	
Single	102 (9.08)	35 (9.00)	67 (9.13)	
Unknown	92 (8.19)	35 (9.00)	57 (7.77)	
Widowed	142 (12.64)	76 (19.54)	66 (8.99)	
Age at diagnosis (years)	66.00±10.65	70.68±9.56	63.51±10.36	<0.0001*
Race				0.0145*
Black	83 (7.35)	39 (9.95)	44 (5.96)	
White	1,047 (92.65)	353 (90.05)	694 (94.04)	

Data are presented as n (%) or mean ± standard deviation. P value comparisons across stage at diagnosis categories are based on Chi-square test of homogeneity for categorical variables; P values for continuous variables are based on the Wilcoxon Rank Sum Test. *, P value <0.05.

https://dx.doi.org/10.21037/tlcr-23-407

Table S4 Association of social determinants of health with the receipt of curative intent surgery for early-stage non-small cell lung cancer (univariable logistic regression analysis)

Covariates	OR	95% CI for OR	P value
Gender			0.6810
Male	1.053	0.824–1.346	0.6810
Female	Reference	–	–
Cigarette use at time of diagnosis			0.2815
Currently smoked	0.742	0.476–1.154	0.1850
Formerly smoked	0.709	0.459–1.095	0.1207
Never used	Reference	–	–
Insurance			<0.0001*
Medicaid	0.407	0.225–0.738	0.0031*
Medicare	0.250	0.180–0.348	<0.0001*
Medicare/Medicaid	0.276	0.145–0.523	<0.0001*
Uninsured	0.167	0.088–0.318	<0.0001*
Private	Reference	–	–
Marital status at diagnosis			<0.0001*
Divorced or separated	0.721	0.478–1.088	0.1190
Single	0.813	0.523–1.263	0.3571
Unknown	0.692	0.440–1.087	0.1099
Widowed	0.369	0.255–0.533	<0.0001*
Married	Reference	–	–
Age at diagnosis (years)	0.928	0.915–0.942	<0.0001*
Race			0.0155*
Black	0.574	0.366–0.900	0.0155*
White	Reference	–	–

*, P value <0.05. OR, odds ratio; CI, confidence interval.

https://dx.doi.org/10.21037/tlcr-23-407

Table S5 Association of social determinants of health with the receipt of radiation therapy for early-stage non-small cell lung cancer (univariable logistic regression analysis)

Covariates	OR	95% CI for OR	P value
Gender			0.3968
Male	0.900	0.706–1.148	0.3968
Female	Reference	–	–
Cigarette use at time of diagnosis			0.0081*
Currently smoked	2.007	1.283–3.141	0.0023*
Formerly smoked	1.486	0.951–2.321	0.0817
Never used	Reference	–	–
Insurance			<0.0001*
Medicaid	1.784	1.019–3.123	0.0427*
Medicare	2.123	1.580–2.852	<0.0001*
Medicare/Medicaid	1.977	1.057–3.698	0.0329*
Uninsured	5.509	2.891–10.499	<0.0001*
Private	Reference	–	–
Marital status at diagnosis			0.0054*
Divorced or separated	1.216	0.807–1.832	0.3502
Single	1.629	1.068–2.487	0.0236*
Unknown	1.154	0.732–1.821	0.5368
Widowed	1.897	1.314–2.737	0.0006*
Married	Reference	–	–
Age at diagnosis (years)	1.039	1.026–1.051	<0.0001*
Race			0.0365*
Black	1.615	1.031–2.531	0.0365*
White	Reference	–	–

*, P value <0.05. OR, odds ratio; CI, confidence interval.

https://dx.doi.org/10.21037/tlcr-23-407

Table S6 Association of social determinants of health with the receipt of systemic therapy for advanced stage non-small cell lung cancer (univariable logistic regression analysis)

Covariate	OR	95% CI for OR	P value
Gender			0.3663
Male	0.911	0.745–1.115	0.3663
Female	Reference	–	–
Cigarette use at time of diagnosis			0.6096
Currently smoked	0.888	0.627–1.257	0.5026
Formerly smoked	1.019	0.698–1.489	0.9213
Never used	Reference	–	–
Insurance			<0.0001*
Medicaid	0.660	0.458–0.950	0.0254*
Medicare	0.531	0.418–0.674	<0.0001*
Medicare/Medicaid	0.246	0.148–0.408	<0.0001*
Uninsured	0.339	0.239–0.482	<0.0001*
Private	Reference	–	–
Marital status at diagnosis			<0.0001*
Divorced or separated	0.737	0.528–1.027	0.0717
Single	0.463	0.346–0.620	<0.0001*
Unknown	0.619	0.436–0.880	0.0075*
Widowed	0.365	0.256–0.521	<0.0001*
Married	Reference	–	–
Age at diagnosis (years)	0.974	0.965–0.983	<0.0001*
Race			<0.0001*
Black	0.524	0.403–0.680	<0.0001*
White	Reference	–	–

*, P value <0.05. OR, odds ratio; CI, confidence interval.

https://dx.doi.org/10.21037/tlcr-23-407

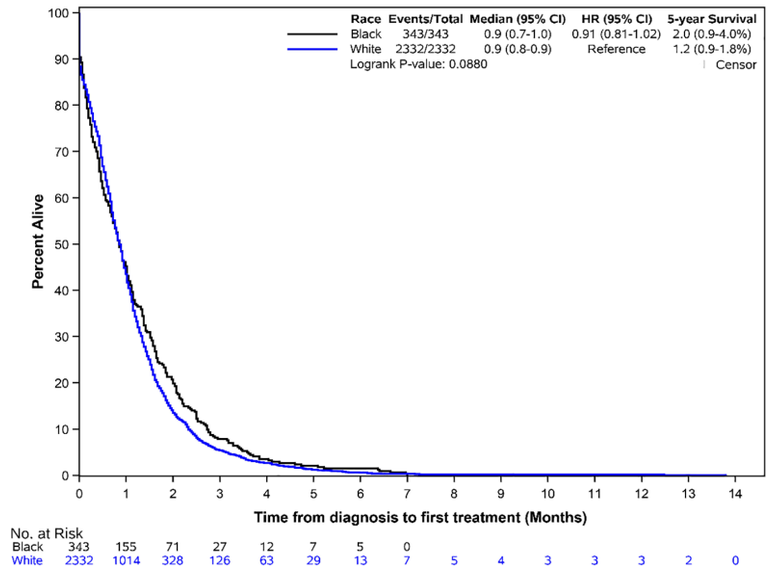

Figure S1 Kaplan-Meier estimates of 5-year overall survival from diagnosis to time of first treatment in months based on race. HR, hazard ratio; CI, confidence interval; No., number.

Table S7 Association of social determinants of health and time from diagnosis to treatment onset (univariable cox proportional hazards regression analysis)

Variables	HR	95% CI for HR	P value
Gender (n=2,678)			0.3963
Male (n=1,402)	1.033	0.958–1.115	0.3963
Female (n=1,276)	Reference	–	–
Cigarette use at time of diagnosis (n=1,607)			<0.0001*
Currently smoked (n=727)	12.856	10.456–15.808	<0.0001*
Formerly smoked (n=573)	52.806	40.957–68.082	<0.0001*
Never used (n=307)	Reference	–	–
Insurance n=2,678)			<0.0001*
Medicaid (n=225)	3.920	3.326–4.619	<0.0001*
Medicare (n=1,215)	10.868	9.473–12.469	<0.0001*
Medicare/Medicaid (n=117)	26.365	20.927–33.217	<0.0001*
Uninsured (n=210)	31.265	25.608–38.172	<0.0001*
Private (n=911)	Reference	–	–
Marital status at diagnosis (n=2,668)			<0.0001*
Divorced or separated (n=285)	3.358	2.924–3.857	<0.0001*
Single (n=326)	8.193	7.075–9.487	<0.0001*
Unknown (n=233)	14.390	12.116–17.091	<0.0001*
Widowed (n=274)	25.865	21.755–30.752	<0.0001*
Married (n=1,550)	Reference	–	–
Age at diagnosis (years) (n=2,678)	0.987	0.984–0.991	<0.0001*
Race (n=2,678)			<0.0001*
Black (n=343)	12.833	11.053–14.9	<0.0001*
White (n=2,335)	Reference	–	–
Stage at diagnosis (n=2,678)			<0.0001*
Advanced stage (n=1,558)	45.883	38.565–54.589	<0.0001*
Early stage (n=1,120)	Reference	–	–

*, P value <0.05. HR, hazard ratio; CI, confidence interval.

https://dx.doi.org/10.21037/tlcr-23-407

Table S8 Association of social determinants of health and time from diagnosis to treatment onset (multivariable cox proportional hazards regression analysis)

Variables	HR	95% CI for HR	P value
Race			0.9076
Black	1.010	0.859–1.187	0.9076
White	Reference	–	–
Cigarette use at time of diagnosis			<0.0001*
Currently smoked	2.440	2.004–2.971	<0.0001*
Formerly smoked	5.218	4.039–6.742	<0.0001*
Never used	Reference	–	–
Insurance			<0.0001*
Medicaid	1.331	1.046–1.694	0.0201*
Medicare	1.705	1.420–2.049	<0.0001*
Medicare/Medicaid	2.381	1.661–3.413	<0.0001*
Uninsured	2.041	1.592–2.618	<0.0001*
Private	Reference	–	–
Marital status at diagnosis			<0.0001*
Divorced or separated	1.131	0.955–1.341	0.1545
Single	1.248	1.033–1.509	0.0219*
Unknown	1.817	1.344–2.458	0.0001*
Widowed	2.109	1.646–2.702	<0.0001*
Married	Reference	–	–
Age at diagnosis (years)	0.992	0.986–0.998	0.0125*
Stage at diagnosis			<0.0001*
Advanced stage	12.738	10.076–16.102	<0.0001*
Early stage	Reference	–	–

*, P value <0.05. HR, hazard ratio; CI, confidence interval.

https://dx.doi.org/10.21037/tlcr-23-407

Table S9 Multivariable Cox proportional hazards regression analysis of overall survival time

Variables	HR	95% CI for HR	P value
Race			0.8320
Black	0.981	0.820–1.174	0.8320
White	Reference	–	–
Gender			0.2209
Male	1.078	0.956–1.215	0.2209
Female	Reference	–	–
Cigarette use at time of diagnosis			0.9853
Currently smoked	1.014	0.868–1.185	0.8633
Formerly smoked	1.009	0.856–1.191	0.9126
Never used	Reference	–	–
Insurance			<0.0001*
Medicaid	1.126	0.838–1.513	0.4305
Medicare	1.970	1.644–2.361	<0.0001*
Medicare/Medicaid	1.756	1.149–2.682	0.0092*
Uninsured	2.658	2.065–3.421	<0.0001*
Private	Reference	–	–
Marital status at diagnosis			0.1020
Divorced or separated	0.970	0.800–1.176	0.7588
Single	1.105	0.922–1.325	0.2780
Unknown	1.112	0.826–1.498	0.4826
Widowed	1.280	1.056–1.552	0.0120*
Married	Reference	–	–
Stage at diagnosis			<0.0001*
Advanced stage	1.672	1.446–1.934	<0.0001*
Early stage	Reference	–	–
Tumor grade			<0.0001*
Well differentiated	Reference	–	–
Moderately differentiated	28.008	17.114–45.838	<0.0001*
Poorly differentiated	329.055	181.465–596.686	<0.0001*
Undifferentiated/anaplastic	922.797	428.347–1,988.004	<0.0001*
Unknown	1,385.829	708.528–2,710.583	<0.0001*

*, P value <0.05. HR, hazard ratio; CI, confidence interval.

https://dx.doi.org/10.21037/tlcr-23-407

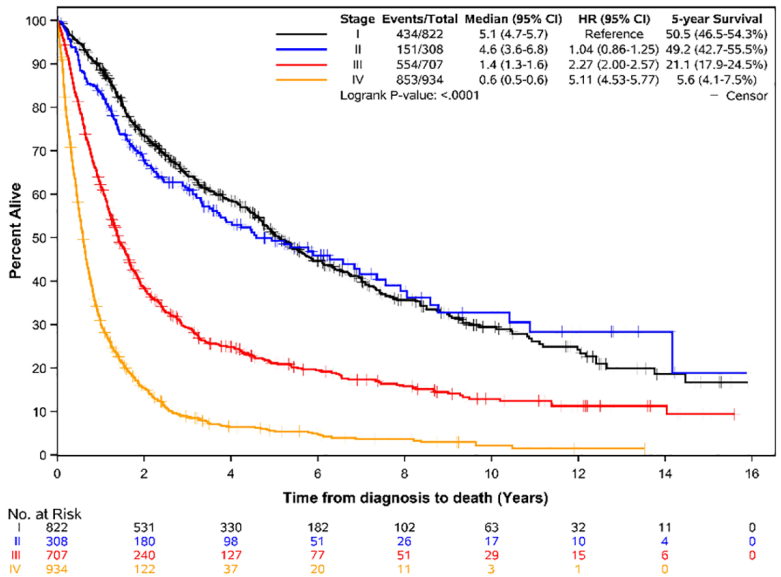

Figure S2 Kaplan-Meier estimates of 5-year overall survival based on stage. HR, hazard ratio; CI, confidence interval; No., number.

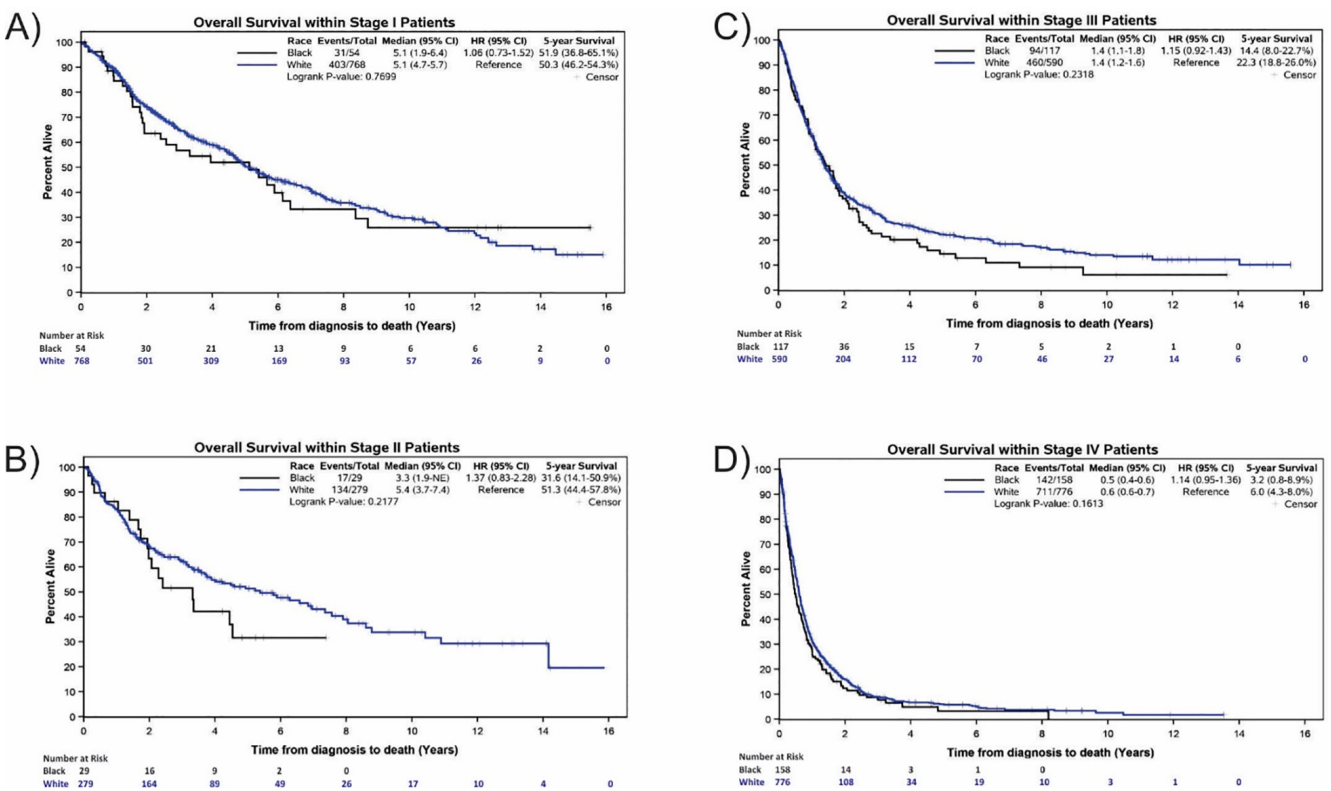

Figure S3 Kaplan-Meier estimates of 5-year overall survival based on lung cancer stage at diagnosis, stratified by race. (A) Stage I. (B) Stage II. (C) Stage III. (D) Stage IV. HR, hazard ratio; CI, confidence interval.

https://dx.doi.org/10.21037/tlcr-23-407