Delays to surgery and worse outcomes: The compounding effects of social determinants of health in non–small cell lung cancer

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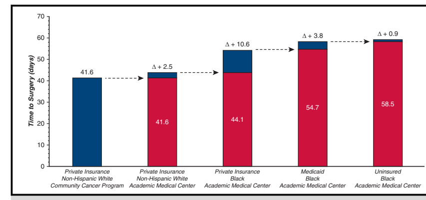
ABSTRACT

Objective: To quantify the compounding effects of social determinants of health on time to surgery (T2S) and clinical outcomes.

Methods: The National Cancer Database was queried for treatment-naïve patients with cT1-4N0-1M0 non–small cell lung cancer undergoing (bi)lobectomy or pneumonectomy between 2006 and 2016 with 1 to 180 days T2S, the number of days between diagnosis and surgery; surgical delays were defined as statistically significant increased T2S compared with a reference cohort. Social determinants of health factors prognostic for surgical delays were identified using multivariable regression. The 30-/90-day mortality and 5-year survival estimates were calculated using logistic and Cox regressions, respectively.

Results: In total, 110,005 patients met inclusionary criteria. Multivariable analysis identified race, insurance, and facility type as factors with significant 3-way interaction: T2S of one depended on the others. Income and education also contributed to delays. Privately insured (private) non-Hispanic White patients at academic medical centers (AMCs) were the reference with T2S of 44.1 days. At AMCs, private Black patients had significant delays to surgery (54.7 days; $P < .0001$), as did Medicaid and uninsured Black patients (58.5 days; $P < .0001$, 59.4 days; $P < .0001$, respectively). The 15-day surgical delays were associated with statistically significant 5% increased 30-day mortality odds (confidence interval [CI], 1.03-1.08), 6% increased 90-day mortality odds (CI, 1.04-1.08), and 4% decrease in hazard of death at 5 years (CI, 1.04-1.05).

Conclusions: In treatment-naïve patients with cT1-4N0-1M0 non–small cell lung cancer, Black race, Medicaid, uninsured status, and AMCs generate compounding surgical delays with increased 30-/90-day mortality and decreased 5-year survival. Thoracic surgeons can leverage these facility and demographic-specific insights to standardize time to surgery and begin mitigating underlying disparities. (JTCVS Open 2023;15:468-78)



Delays to surgery according to various permutations of insurance, race, and facility type.

CENTRAL MESSAGE

Black race, Medicaid insurance, uninsured status, and academic medical centers generate compounding delays to surgery associated with increased 30-/90-day mortality and decreased 5-year survival.

PERSPECTIVE

There is no discussion on the compounding effects of social determinants of health on time to surgery, let alone with stratification of risk factors and coupling with clinical outcomes. Existing studies focus on individual risk factors with no compounding insights. This study's novel analysis will address these knowledge gaps and help surgeons understand the disparities facing their patients.

See Discussion on page 479.

Lung cancer is the leading cause of cancer death in the United States and the second most common cancer in men and women.[1] With a growing elderly population and the number of new lung cancer diagnoses remaining high, the importance of efficient thoracic surgery programs will be increasingly paramount. One aspect of efficiency is time to surgery, which can theoretically both lower the risk of disease progression and maximize surgical throughput. In addition to institutional characteristics (eg, practice location) both clinical and social determinants of

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Abbreviations and Acronyms

AJCC	= American Joint Committee on Cancer
AMC	= Academic medical center
CI	= confidence interval
CoC	= Commission on Cancer
NCDB	= National Cancer Database
NSCLC	= non–small cell lung cancer
SDoH	= social determinants of health

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health (SDoH) risk factors play important roles in time to surgery.

Racial disparities in lung cancer are well-documented, whereby Black patients have a lower likelihood of receiving surgical therapy, increased cancer-related mortality, and decreased 5-year survival compared with White patients.[2-4] Public insurance status (eg, Medicaid) and facility type where patients receive surgery (eg, academic medical centers) have similarly been correlated with significant delays to surgery.[5-8] These delays to surgery have been associated with worse survival,[9] improved survival,[10] or found to have no effect on survival,[11] and thus there is limited consensus. More data are needed to elucidate better the effects of delayed surgery on clinical outcomes.

Much of the existing literature evaluating the impact of SDoH on time to surgery has analyzed individual risk factors independently with limited investigation into the potential compounding effects in patients with multiple risk factors. The objectives of this study were to identify the SDoH factors prognostic for delayed time to surgery and quantify the compounded impact on surgical delays and associated changes in clinical outcomes (ie, 30-/90-day mortality and 5-year survival). With this information, thoracic surgeons can better understand potential disparities in surgical timing and outcomes and develop mitigating strategies to ensure equitable care for all patients.

METHODS

Data Source

The National Cancer Database (NCDB) is a hospital-based clinical oncology tumor registry maintained as a joint effort of the American College of Surgeons and the American Cancer Society. The NCDB contains more than 34 million historical records of patients with cancer obtained from more than 1500 Commission on Cancer (CoC)-accredited facilities, representing approximately 70% of patients diagnosed annually with cancer. The NCDB maintains that "data used in the study are derived from a deidentified NCDB file. The American College of Surgeons and the CoC have not verified and are not responsible for the analytic or statistical methodology employed, or the conclusions drawn from these data by the investigator."[12] The institutional review board or equivalent ethics committee of the University of Southern California approved the study protocol and publication of data (number: HS-16-00906; approval date: December 19, 2016). Patient written consent for the publication of the study data was waived by the institutional review board because this study is not considered human subjects research.

Study Population and Design

The NCDB Participant User Data File was used to identify patients diagnosed with non–small cell lung cancer (NSCLC) without preoperative chemotherapy or radiation therapy who underwent lobectomy, bilobectomy, or pneumonectomy of clinical stage T1-4N0-1M0 from 2006 to 2016 with a time to surgery between 1 and 180 days. Time to surgery was defined as the number of days between the date of diagnosis and date of surgery. Patients undergoing surgery on the same day as diagnosis were omitted to minimize potential confounding factors regarding treatment context not available in the NCDB. Delays to surgery were defined as statistically significant increases in time to surgery as compared with a reference cohort. Patients with tumor size missing were excluded (Figure 1).

Demographic variables included sex, race, insurance, facility type, hospital urban/rural designation, distance from hospital, education, income, and age. Clinical and tumor specific variables included American Joint Committee on Cancer (AJCC) clinical stage, AJCC clinical T, AJCC clinical N, histology, Charlson–Deyo score, and tumor size ($\leq$3, 3-5, 5-7, and >7 cm). Histology was subdivided into adenocarcinoma, squamous cell carcinoma, and other. Age was categorized by quartiles based on median and interquartile range. The tumor size cutoffs were chosen in accordance to the eighth edition TNM NSCLC staging classification system.

Statistical Analysis

Time to surgery was reported as means and standard deviation stratified by patient demographic variables, clinical variables, and hospital variables, and compared by *t*-test or analysis of variance when appropriate. Multivariable zero-truncated negative binomial regression was used to determine the association between race, insurance, facility type and time to surgery, adjusting for tumor size, age, sex, AJCC clinical T stage, N stage, histology type, Charlson–Deyo comorbidity score, hospital urban–rural designation, and distance from hospital. Two-way interactions between all SDoH factors were included initially. Interactions not significant were dropped. The Akaike information criterion was used for model comparisons. The final model included main effect for all variables, 2-way and 3-way interaction between race, insurance, and facility type. Results of the multivariable regression were reported as marginal means with 95% confidence intervals (CIs), with the marginal mean defined as the average time to surgery after adjusting for all other covariates. Multivariable logistic regression was used for 30-day and 90-day mortality. The same covariates were included in the model—except AJCC pathologic T and N were used instead of clinical stage—with the additions of time to surgery and surgical margin. Data missingness was less than 2%; as such, only complete cases were used for the regression analysis. Hosmer–Lemeshow goodness-of-fit test was used for model fitting assessment. Log-rank test was used for 5-year overall survival from postsurgery. Multivariable Cox regression was used for adjusting covariates same as 30-day and 90-day mortality and added if patients were on adjuvant therapy. The full list of variables used in the Cox regressions include tumor size, age, time to surgery, surgery type, AJCC pathologic T stage, AJCC pathologic N stage, sex, race, insurance, facility type, urban–rural location, great circle distance, education, income, histology, Charlson–Deyo score, and surgical margin. Proportional hazard assumption and linearity of time to surgery was assessed using Schoenfeld residuals. Significance level was .05, two-sided. Zero-truncated negative binomial regression was conducted using STATA 17 (StataCorp. 2021.). All other analyses were conducted in SAS 9.4. (SAS Institute Inc).

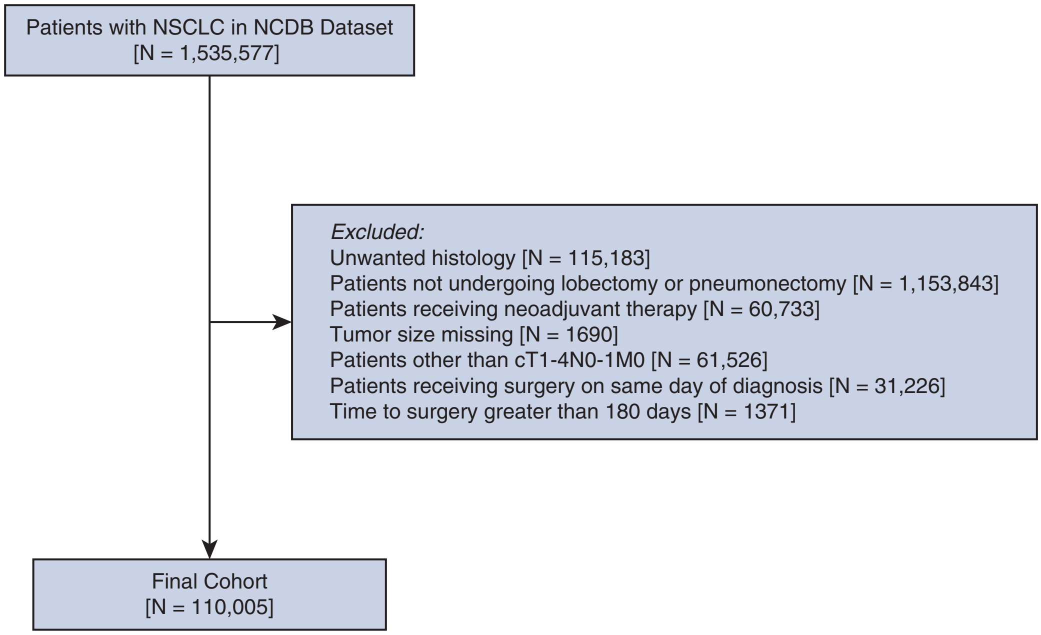

FIGURE 1. A schematic diagram showing the cohort selection process whereby the final cohort contained 110,005 patients. *NSCLC*, Non–small cell lung cancer; *NCDB*, National Cancer Database.

RESULTS

In total, 110,005 patients met inclusionary criteria. Mean time to surgery was 45.8 ± 29.8 days with a median of 39 (interquartile range, 26-59) days and a range of 1 to 180 days (Figure 2). On univariate analysis, patients with longer time to surgery were significantly more likely to be male, Black, uninsured, Medicaid enrollees, receive surgery at academic medical centers (AMCs), urban, live farther away from the hospital, less educated, have lower income, have squamous cell histology, and have greater comorbidities per the Charlson–Deyo index (Table 1). They were also significantly more likely to be younger. Across the

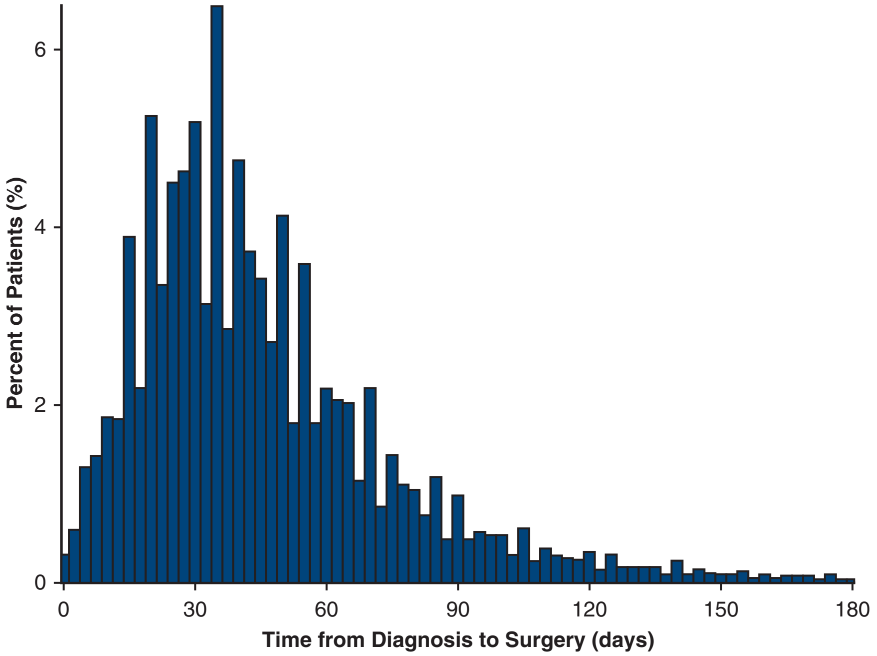

FIGURE 2. The distribution of time from diagnosis to surgery as a percent of the total patient cohort (N = 110,005) with a mean of 45.8 ± 29.8 days, median of 39 (interquartile range, 26-59) days, and a range of 1 to 180 days.

TABLE 1. Univariate analysis of demographic and clinical characteristics of the patients in the NCDB on time to surgery (N = 110,005)

Characteristic	Total N	%	Time to surgery		*P* value
			Mean, d	Standard deviation	
Sex					<.0001
Male	54,113	49.19	46.21	29.71	
Female	55,892	50.81	45.4	29.32	
Race					<.0001
Missing	622	0.57	45.67	28.38	
Hispanic White	6282	5.71	45.37	29.91	
Black	9075	8.25	53.78	33.7	
Other	3363	3.06	47.64	31.24	
Non-Hispanic White	90,663	82.42	44.96	28.85	
Insurance					<.0001
Missing	1043	0.95	47.46	29.51	
Not insured	1977	1.8	50.1	34.24	
Medicaid	5418	4.93	53.7	34.24	
Medicare	68,717	62.47	46.51	29.51	
Other	1175	1.07	49.92	31.23	
Private insurance	31,675	28.79	42.43	27.81	
Facility type					<.0001
Missing	339	0.31	36.82	27.24	
Community care program (CCP)	6425	5.84	45.42	29.74	
Comprehensive community cancer program (CCCP)	49,001	44.54	44.27	28.69	
Integrated network cancer program (INCP)	15,626	14.2	46.06	28.79	
Academic medical center (AMC)	38,614	35.1	47.78	30.66	
Urban–rural					.0004
Counties in metro areas of 250,000 to 1 million population	23,952	21.77	46.34	29.29	
Counties in metro areas of fewer than 250,000 population	11,852	10.77	45.15	28.89	
Other	22,522	20.47	45.41	29.21	
Counties in metro areas of 1 million population or more	51,679	46.98	45.87	29.88	
Great circle distance					.01
Missing	247	0.22	46.95	32.66	
>12.5 miles	59,205	53.82	46	29.57	
≤12.5 miles	50,553	45.96	45.56	29.43	
Education					<.0001
Missing	1192	1.08	47.19	30.94	
≥21.0% no high school degree	21,047	19.13	48.19	31.6	
13.0%-20.9% No High School Degree	30,977	28.16	47.12	29.94	
7.0%-12.9% no high school degree	31,828	28.93	45.57	28.66	
<7.0% no high school degree	24,961	22.69	42.37	27.79	
Income					<.0001
Missing	1410	1.28	47.3	30.89	
<$38,000	21,177	19.25	48.99	31.59	
$38,000-$47,999	25,891	23.54	46.36	29.44	
$48,000-$62,999	26,606	24.19	45.34	28.72	
≥$63,000	34,921	31.74	43.75	28.61	
AJCC clinical stage					.14
1	73,631	66.93	45.68	29.79	
2	23,935	21.76	46.1	29.01	
3	12,439	11.31	45.93	28.81	
AJCC clinical T					.09
1	50,694	46.08	45.88	30.17	
2	37,188	33.81	45.52	28.9	
3	11,705	10.64	46.23	29	
4	10,418	9.47	45.93	29	

(Continued)

TABLE 1. Continued

Characteristic	Total N	%	Time to surgery Mean, d	Standard deviation	P value
AJCC clinical N					.99
c0	99,149	90.13	45.8	29.63	
c1	10,856	9.87	45.8	28.44	
Histology					<.0001
Adenocarcinoma	69,344	63.04	45.35	29.6	
Squamous cell carcinoma	36,634	33.3	46.79	29.36	
Other	4027	3.66	44.48	29.26	
Charlson–Deyo score					<.0001
0	53,878	48.98	44.45	28.92	
1	37,934	34.48	46.05	29.63	
2	13,307	12.1	48.62	30.37	
≥3	4886	4.44	50.99	31.53	

AJCC, American Joint Committee on Cancer.

overall cohort, lobectomies comprised 95% of surgical volume (ie, 104,255 of 110,005 procedures) and ranged from 89% to 96% across individual cohorts (Table 2).

After adjusting for all other covariates, multivariable analysis identified race, insurance status, facility type, education, and income as SDoH factors prognostic for prolonged time to surgery. Further, the 3-way interaction between race, insurance, and facility type was significant, meaning that the time to surgery of one factor depended on the other two. Non-Hispanic White patients with private insurance undergoing surgery at AMCs were designated the reference group (marginal mean, 44.1 days) for statistical analysis of time to surgery. Black patients with private insurance undergoing surgery at AMCs had statistically significant delays to surgery (54.7 days; $P < .0001$). Uninsured Black patients undergoing surgery at AMCs had the longest average time to surgery at 59.4 days ($P < .0001$), followed closely by Black patients with Medicaid at AMCs (58.5 days; $P < .0001$) (Figure 3), a 15-day difference compared to the reference group. Non-Hispanic White patients at AMCs experienced similar delays to surgery when uninsured (55.5 days; $P < .0001$) or with Medicaid (58.5 days; $P < .0001$). Medicare insurance was also significantly associated with delayed time to surgery, albeit less drastically, whereby—at AMCs—non-Hispanic White patients averaged 47.1 days ($P < .0001$) and Black patients 55.7 days (Table 2).

Across each race, insurance, and facility permutation, AMCs consistently had the longest time to surgery. For example, non-Hispanic White patients with private insurance had faster time to surgery at community cancer programs, comprehensive community cancer programs, or integrated network cancer programs compared with AMCs at 41.6, 42.2, and 42.6 days, respectively. Although still slower than non-Hispanic White patients, Black patients with private insurance experienced similar relative improvements in time to surgery at community cancer programs, comprehensive community cancer programs, and integrated network cancer programs at 48.3, 47.5, and 51.0 days, respectively, compared with AMCs (54.7 days) (Table 2).

Delayed time to surgery was significantly associated with increased 30-day and 90-day mortality and worse 5-year survival. A 15-day prolongation in time to surgery was associated with 5% increased odds of 30-day mortality (odds ratio, 1.05; 95% CI, 1.03-1.08; $P < .0001$), 6% increased odds of 90-day mortality (odds ratio, 1.06; 95% CI, 1.04-1.08; $P < .0001$), and 4% decrease in the hazard of death at 5 years (hazard ratio, 1.04; 95% CI, 1.04-1.05; $P < .0001$).

After adjusting for all other covariates, education and income were other SDoH factors independently associated with delayed surgery: highest rates of high school degree attainment and highest levels of income were associated with faster time to surgery (43.0 days and 45.0 days, respectively) compared with the lowest rates of education and income (46.5 days and 46.8 days, respectively). Charlson–Deyo score was also associated with longer time to surgery: CD0: 44.4, CD1: 45.9, CD2: 48.0, and CD3+: 50.0 average days.

DISCUSSION

In this study of 110,005 patients from the NCDB with treatment-naïve cT1-4N0-1M0 NSCLC, a 3-way interaction model developed herein illustrates the compounding effects of race, insurance status, and facility type on time to surgery. Starting with the fastest time to surgery cohort, incremental changes to one of the 3 variables yield corresponding progressive delays to surgery (ie, from 41.6 days to 59.4 days, approximately an 18-day difference). Any permutation of these SDoH risk factors can be selected, the corresponding time to surgery identified, and potential significant difference elucidated. Coupled with the 30-/90-day mortality and 5-year survival estimates,

TABLE 2. The average time to surgery for select permutations of the 3-way interaction multivariable model* with accompanying breakdown of lobectomy versus pneumonectomy volume

Race* insurance* facility type	No. patients	Time to surgery, d	95% confidence interval	Difference in time to surgery	*P* value	% lobectomy ‖ % pneumonectomy
Non-Hispanic White, private, AMC	9206	44.1	43.5-44.7	Reference	Reference	93% ‖ 7%
Non-Hispanic White, private, CCP	1374	41.6	40.3-43.0	–2.5 d	.002	92% ‖ 8%
Non-Hispanic White, Medicare, AMC	18,197	47.1	46.7-47.6	+3.0 d	<.0001	96% ‖ 4%
Non-Hispanic White, Uninsured, AMC	498	55.5	52.4-58.5	+11.4 d	<.0001	89% ‖ 11%
Non-Hispanic White, Medicaid, AMC	1271	58.5	56.5-60.5	+14.4 d	<.0001	91% ‖ 9%
Black, private, AMC	1210	54.7	52.8-56.6	+10.6 d	<.0001	95% ‖ 5%
Black, Medicare, AMC	2120	55.7	54.2-57.2	+11.6 d	<.0001	96% ‖ 4%
Black, Medicaid, AMC	540	58.5	55.4-61.6	+14.4 d	<.0001	92% ‖ 8%
Black, uninsured, AMC	187	59.4	54.1-64.7	+15.3 d	<.0001	92% ‖ 8%
Non-Hispanic White, private, CCCP	11,269	42.2	41.7-42.7	–1.9 d	<.0001	93% ‖ 7%
Non-Hispanic White, private, INCP	3486	42.6	41.7-43.5	–1.5 d	<.0001	93% ‖ 7%
Black, private, CCP	95	48.3	42.3-54.4	+4.2 d	.151	92% ‖ 8%
Black, private, CCCP	866	47.6	45.6-49.6	+3.5 d	.001	95% ‖ 5%
Black, private, INCP	383	51.0	47.8-54.1	+6.9 d	<.0001	95% ‖ 5%

The top half focuses on race and insurance; the bottom half focuses on facility type. The number of patients, 95% confidence interval, difference in time to surgery, and *P* value for each permutation are also listed. *AMC*, Academic medical center; *CCP*, community cancer program; *CCCP*, comprehensive community cancer program; *INCP*, integrated network cancer program. *A multivariable zero-truncated negative binomial regression used to determine the association between race, insurance, facility type and time to surgery adjusted for tumor size, age, sex, American Joint Committee on Cancer clinical T stage, N stage, histology type, Charlson–Deyo comorbidity score, hospital urban–rural designation, and distance from hospital.

thoracic surgeons can more readily quantify the surgical timing and potential outcome disparities among their patients (Figure 4).

A key difference between the present study and existing literature is the definition of delayed surgery. Previous investigators have defined treatment delays using a dichotomized approach where, for example, surgical resection 8 weeks or more after diagnosis,[9] greater than 30 days after diagnosis,[5] or greater than the median time to surgery (eg, 38 days)[13] were defined as delayed. However, the present study uses time as a continuum and defines a delay as any statistically significant increase in time to surgery compared to the reference cohort, which allows for more targeted and nuanced analyses of the impacts of SDoH.

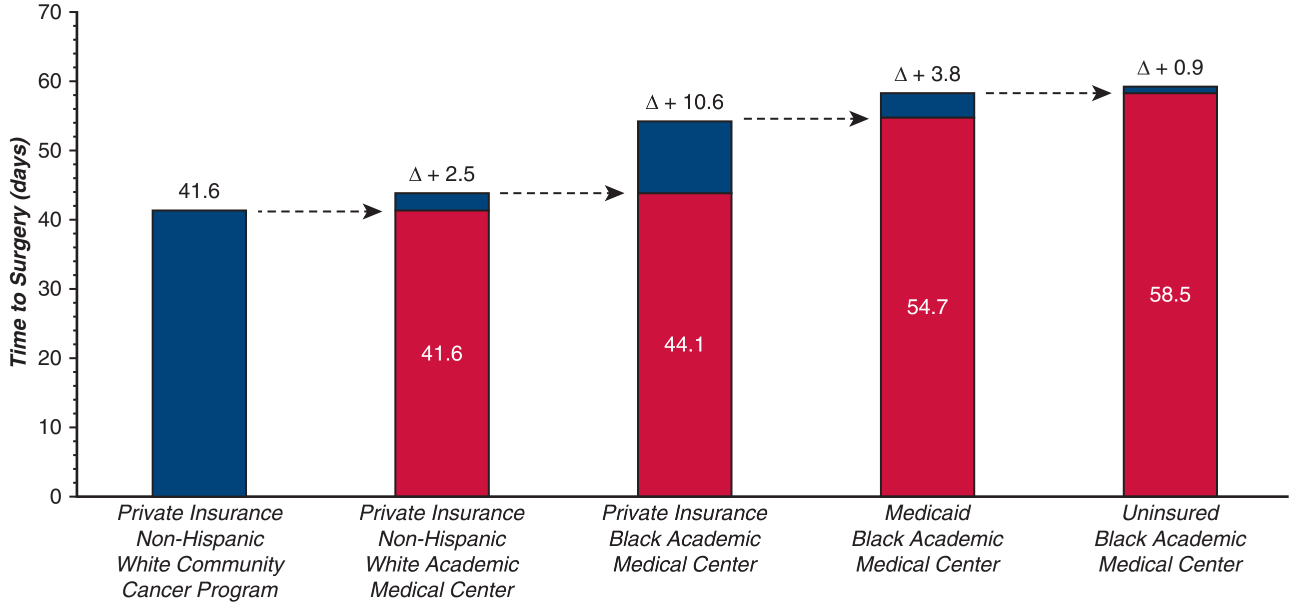

FIGURE 3. Time to surgery for several permutations of insurance type, race, and facility type per the 3-way interaction model. From *left to right*, the incremental delays to surgery are illustrated from one patient cohort to the next.

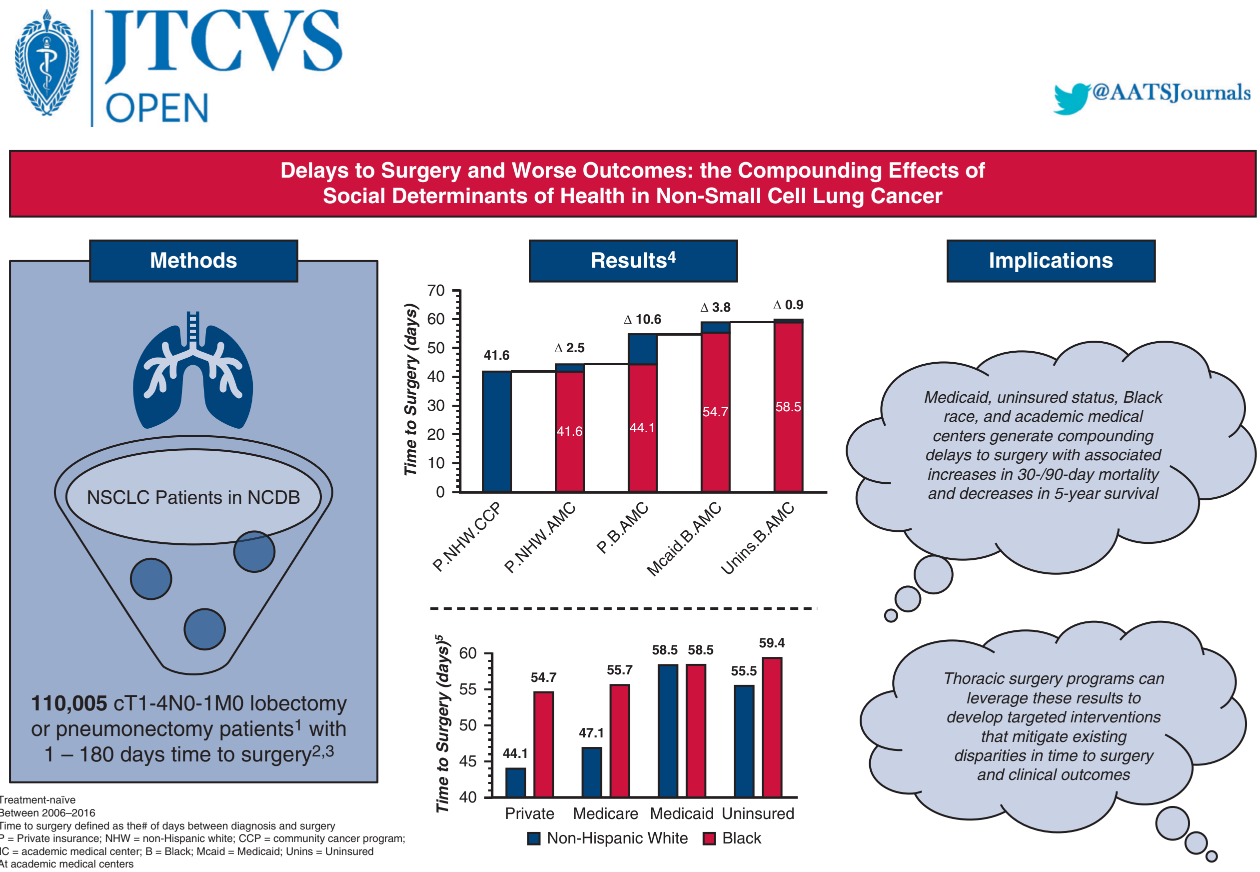

FIGURE 4. Summary of the methods, results, and implications of this study. *NSCLC*, Non–small cell lung cancer; *NCDB*, National Cancer Database.

Although some studies on this topic have employed national databases,[5,7,13] others have performed more targeted analyses. Yorio and colleagues[14] studied their public and private hospital affiliates with Schultz and colleagues[8] studying the Veterans Affair system, whereas Neroda and colleagues[6] used the state of Louisiana as a case study. Despite painting a more detailed picture, these analyses are less applicable to other institutions who may be structurally dissimilar and/or have different patient demographics. Therefore, by broadening the scope to all United States geographies and facility types, the external validity of this study increases and the outputs more widely applicable.

The racial disparities in time to surgery presented herein are consistent with previous investigations that showed race was associated with delays to surgery.[9,10,13] In their NCDB study, Holmes and Chen[15] found that when compared with White patients, African American patients had statistically longer median time to treatment (ie, 31 vs 26 days, an 8.2-day delay; treatment defined as surgery, stereotactic body radiotherapy, or conventional radiotherapy). Additionally, they found that Medicare, Medicaid, or uninsured patients had surgical delays compared to privately insured patients (2.3, 10.8, and 7.8 days, respectively), in accordance with other publications.[6,9,13] Similarly, Neroda and colleagues[6] identified delayed surgery for Black patients compared with White patients (ie, 42 vs 27 days, respectively). Although these results are in alignment with the current study, no multivariate analysis used an interaction model to assess the compounding effects of race and insurance status, let alone include facility type as a risk factor.

In this study, the racial disparities in time surgery were most pronounced when comparing Black and non-Hispanic White patients with private insurance and Medicare, with differences of 10.6 and 8.6 days, respectively (Figure 5, *A*). However, these racial disparities disappear when comparing Medicaid and uninsured status, with differences of 0 and 3.9 days, respectively (Figure 5, *B*). Paradoxically, if patients have Medicaid or are uninsured, then there are minimal-to-no racial disparities, whereas if patients have private insurance or Medicare, then race does play a role in determining time to surgery. This finding further supports the conclusion that SDoH have codependent and compounding effects on time to surgery.

The notion that academic centers have the greatest delay to surgery has been identified by others[8,9,14] and may initially be surprising. However, given that AMCs are often referred more complex patients from community hospitals and that some patients often seek second opinions, this

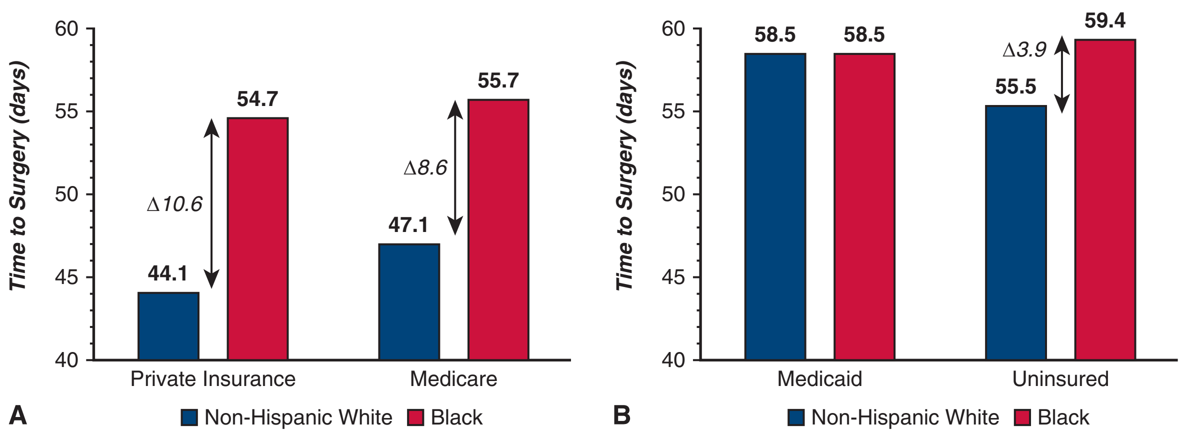

FIGURE 5. Differences in time to surgery between insurance types for non-Hispanic White versus Black patients at academic medical centers. A, There is a substantial difference in time to surgery between non-Hispanic White and Black patients for both Private and Medicare insurance types at 10.6 days and 8.6 days, respectively. B, The difference in time to surgery between non-Hispanic White and Black patients is nonexistent for Medicaid patients (ie, no difference) and much smaller for uninsured patients (ie, 3.9 days). Medicaid and uninsured patients have the longest time to surgery.

delay can be rationalized. Similarly, the association between increasing Charlson–Deyo score and increased time to surgery has been demonstrated in previous studies,[5,9,10] a phenomenon potentially due to lengthened diagnostic work-up intervals or additional time required to optimize patients for surgery.

The effect of time to surgery on clinical outcomes has been debated in the literature. The results presented herein demonstrating statistically significant increased 30-day and 90-day mortality and reduced 5-year survival is consistent with many leading papers. Samson and colleagues[9] found increased 30-day mortality (ie, 2.9% vs 2.4%) and decreased median survival (ie, 57.7 ± 1.0 months vs 69.2 ± 1.3 months) for those patients with delays in care compared with adequate surgical timing. Yang and colleagues[13] also calculated a worse 5-year survival for those undergoing delayed. While corroborating the outputs from these studies and others like it,[16] this finding contradicts others that either did not identify any survival differences associated with surgical timing[11,17] or conversely identified a survival advantage with delayed surgery.[10,18] The observed differences may be due to clinically insignificant delays to surgery, a selection bias of patients with advanced disease who necessitate more urgent intervention, or a potential analytical bias owing to the use of a single metric (ie, time to surgery) associated with clinical outcomes thereby creating an inference of true effect. Nonetheless, these clinical outcomes results can help quantify the expected changes in survival and mortality associated with any combination of race, insurance, and facility type. For instance, those cohorts with approximately 15-day delays to surgery compared with the reference (eg, 15.3-day delay for uninsured black patients at AMCs) may have an associated 5% increased 30-day mortality odds, and 6% increased 90-day mortality odds, and 4% decrease in hazard of death at 5 years.

It is important to note that although time to surgery was the primary metric used in this study, the associated clinical outcomes cannot and should not be attributed solely to delays to surgery. There are many other potential uncontrolled confounding factors that may be influenced by SDoH that impact outcomes or conditioning on colliders. For instance, the US Department of Health and Human Services groups SDoH into 5 domains: economic stability, education access and quality, health care access and quality, neighborhood and built environment, and social and community context. Although the focus of the present study corresponds to the singular health care access and quality domain, it nonetheless is a domain that may likely be a marker of issues in the other 4 domains that, together, cumulatively contribute to delays and driving clinical outcomes. It should be noted that one crucial factor that cannot be quantified with the NCDB dataset is patient attitude toward health care and their providers, whereby historic racial disparities in these perceptions exist. Nonetheless, the ultimate goal is to reduce the proportion of people who cannot access medical care when they need it, which is in alignment with one objective of the U.S. Department of Health and Human Services' Healthy People 2030 initiative.[19]

There are several limitations associated with using the NCDB for this retrospective study. The NCDB captures only 70% of all cancer cases, meaning that patients from non–CoC-accredited centers are not captured. Although this may inherently introduce a sampling bias with certain patient populations or geographies being over- or underrepresented, the exact effect on the social determinant of health analysis cannot be determined.[20] At the same time, using this expansive national data registry allows for greater generalizability of the study findings to thoracic surgery programs nationwide. Time to surgery is a very complex process that has been simplified to the difference between diagnosis date and surgery date for this analysis, whereas certain patient and clinical reasoning data not captured by the NCDB could help explain any observed delayed time to surgery. For example, delays could result from additional diagnostic imaging opposed to a true delay in care. The time to surgery calculation is further complicated by inconsistent NCDB coding practices for the "date of diagnosis," which allows for a range of dates based on radiologic, histologic, or clinical criteria.[21] Thus, the discussion of delayed surgery may be prone to uncontrollable misclassification bias.

Beyond the potential complications regarding time to surgery's definition, it is possible that some patients may have been inadequately staged and did not undergo systemic therapy when they could have received it as an appropriate treatment option. It is also possible that surgeons deemed their patients to have completely resectable disease (ie, R0 resection). Nevertheless, surgical therapy as a first-line treatment option for cT1-4N0-1M0 disease remains a guideline concordant option.[22] The observation that some patients with T4N0 and T3-4N1 disease did not undergo systemic therapy before surgery could be a potential source of selection bias that unfortunately cannot be controlled for given the lack of insight into clinical judgment and rationale for treatment plans in the NCDB. The fact that some patients who were eligible for systemic therapy but did not receive it could represent an insidious source of social disparities in access to quality care.

Another potential limitation is the present study excludes patients undergoing sublobar resections and thus may not capture the full spectrum of surgical volume. For patients undergoing pneumonectomy or lobectomy though, there are no potential lesser surgical resections and thus less ambiguity regarding the type of indicated operation. However, the clinical rationale (eg, medically less fit, noncurative intent or diagnostic resections) behind patients undergoing sublobar resection is unknown and can be more variable. Given this known limitation of the NCDB, the intent of the present study was to focus on a more homogenous cohort that would minimize the potential to introduce other bias(es), blind spots, or confounders.

The lack of clinical decision-making data in the NCDB may have provided insight as to why 31,226 (~30% of the total sample size) patients received surgery on the same date of diagnosis, an exclusionary criterium in this study. Be it a lack of preoperative diagnosis of NSCLC, pathological diagnosis only on surgical specimen, or transfers from non-CoC centers, this a subset of the 31,226 patients may have otherwise met inclusionary criteria for this study. To ensure the integrity of the output, a sensitivity analysis was performed whereby patients undergoing surgery on the same day as diagnosis (ie, time to surgery of zero days) were *included*. Average time to surgery expectedly decreased across all cohorts (eg, 44.1-37.2 days for the reference cohort) (Table E1). For clinical outcomes however, the 30-day/90-day mortality odds and 5-year hazard of death rates were nearly identical: 5% versus 4%, 6% versus 5%, and 4% versus 4% when excluding versus including patients with time to surgery of zero, respectively (Table E2), suggesting robustness of the clinical outcomes analysis.

In conclusion, this paper represents an attempt to quantify the compounding impact of SDoH on time to surgery and the changes in clinical outcomes associated with delayed surgery. The 3-way interaction model of race, insurance, and facility type was significant, meaning the time to surgery of one risk factor also depended on the others. With this model, any combination of these variables can be selected and the corresponding time to surgery stratified by practice type (eg, academic center or integrated health network). Coupled with the study's clinical and geographic generalizability, these outputs can be used by any hospital-based thoracic surgery program to develop targeted interventions that standardize time to surgery according to the racial and insurance breakdown of their patient population. Whether that is additional transportation services or streamlined diagnostic imaging process will be hospital-dependent. Additionally, programs can better understand disparities in timing of surgical care and clinical outcomes and, for example, implement recurrent implicit bias trainings for health care teams to help mitigate these disparities. Crucially, time to surgery is but one metric of many underpinning these disparities and serves as a bellwether for other indices. With a continued shift towards outcomes-based payment and projected increased demand for thoracic surgery, minimizing the clinical disparities associated with SDoH will increasingly become a topic of importance that the insights from this study can support.

Webcast

You can watch a Webcast of this AATS meeting presentation by going to: https://www.aats.org/resources/the-compounding-effects-of-social-determinants-of-health-delayed-time-to-surgery-and-worse-clinical-outcomes-in-treatment-na%C3%AFve-non-small-cell-lung-cancer.

Conflict of Interest Statement

The authors reported no conflicts of interest.

The *Journal* policy requires editors and reviewers to disclose conflicts of interest and to decline handling or reviewing manuscripts for which they may have a conflict of interest. The editors and reviewers of this article have no conflicts of interest.

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Key Words: thoracic surgery, NSCLC, social determinants of health, time to surgery, clinical outcomes, disparities

TABLE E1. Comparison of time to surgery between the primary analysis that excludes time to surgery of zero days and sensitivity analysis that includes those patients with time to surgery of zero days

Cohort	Excluding time to surgery = 0 d				Including time to surgery = 0 d			
	Avg time to surgery*	95% CI	N	*P* value	Avg time to surgery*	95% CI	N	*P* value
Non-Hispanic White, Private, AMC	44.1	43.5-44.7	9206	Reference	37.2	36.1-38.5	11,889	Reference
Non-Hispanic White, Private, CCP	41.6	40.3-43.0	1374	.002	33.8	31.7-36.1	1828	.005
Non-Hispanic White, Medicare, AMC	47.1	46.7-47.6	18,197	<.0001	40.1	39.1-41.2	22,999	<.0001
Non-Hispanic White, Uninsured, AMC	55.5	52.4-58.5	498	<.0001	50.5	45.2-56.4	585	<.0001
Non-Hispanic White, Medicaid, AMC	58.5	56.5-60.5	1271	<.0001	52.6	49.0-56.5	1524	<.0001
Black, private, AMC	54.7	52.8-56.6	1210	<.0001	46.8	43.6-50.3	1545	<.0001
Black, Medicare, AMC	55.7	54.2-57.2	2120	<.0001	48.6	45.9-51.4	2625	<.0001
Black, Medicaid, AMC	58.5	55.4-61.6	540	<.0001	51.3	46.2-56.9	670	<.0001
Black, uninsured, AMC	59.4	54.1-64.7	187	<.0001	55.9	46.6-66.9	216	<.0001
Non-Hispanic White, Private, CCCP	42.2	41.7-42.7	11,269	<.0001	35.4	34.3-36.5	14,576	.003
Non-Hispanic White, private, INCP	42.6	41.7-43.5	3486	<.0001	35.6	34.1-37.2	4549	.062
Black, private, CCP	48.3	42.3-54.4	95	.151	37.5	29.8-47.3	131	.944
Black, private, CCCP	47.6	45.6-49.6	866	.001	40.1	36.9-43.5	1125	.084
Black, private, INCP	51.0	47.8-54.1	383	<.0001	42.8	37.9-48.3	498	.023

Avg, Average; *CI*, confidence interval; *N*, number of patients; *AMC*, academic medical center; *CCP*, community cancer program; *CCCP*, comprehensive community cancer program; *INCP*, integrated network cancer program. *Time to surgery in days.

TABLE E2. Comparison of clinical outcomes associated with 15-day delays to surgery between the primary analysis that excludes time to surgery of zero days and sensitivity analysis that includes those patients with time to surgery of zero days

Clinical outcomes	Excluding time to surgery = 0 d			Including time to surgery = 0 d		
	OR/HR	95% CI	*P* value	OR/HR	95% CI	*P* value
15-d mortality	OR, 1.05	1.03-1.08	<.0001	OR, 1.04	1.02-1.06	<.0003
30-d mortality	OR, 1.06	1.04-1.08	<.0001	OR, 1.05	1.03-1.06	<.0001
5-y survival	HR, 1.04	1.04-1.05	<.0001	HR, 1.04	1.03-1.05	<.0001

OR, Odds ratio; *HR*, hazard ratio; *CI*, confidence interval.