Delays in phases of care from identification to treatment of suspicious lung nodules

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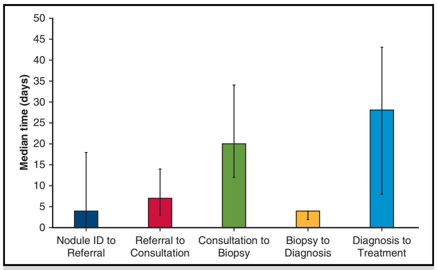
ABSTRACT

Objectives: Shorter time to lung cancer diagnosis and treatment is associated with improved outcomes. We analyzed the time spent from nodule identification to treatment to identify targets for improving the timeliness of suspicious lung nodule care in a diverse patient population.

Methods: This was a retrospective cohort study of patients with suspicious lung nodules (suspected clinical stage I/II primary lung cancer) at a single academic medical center (2020-2022). Patients with suspected stage III/IV or nonprimary lung cancers were excluded. Multivariable Cox regressions were performed to assess factors associated with timeliness of care.

Results: Of 157 patients, 59% were female, 53% were Black, and mean age was 70 ± 8.6 years. Nodules were identified incidentally (52%) or via screening (48%). Treatment was surgery in 52% and stereotactic body radiotherapy in 44%, and 10.2% were benign. Median (interquartile range) times from referral to diagnosis and from referral to treatment were 34 (22-56) days and 65 (44-84) days, respectively. Consultation to biopsy (20 [12-34] days) and diagnosis to treatment (28 [8-43] days) were the longest phases of care. Longer time from referral to diagnosis was associated with Black race and widowed status, whereas longer time from referral to treatment was associated with female gender, widowed status, frailty, body mass index greater than 18.5, Eastern Cooperative Oncology Group performance status less than 2, bronchoscopic biopsy, and treatment with stereotactic body radiotherapy.

Conclusions: Increased time spent in suspicious lung nodule care is associated with demographic, social, and clinical factors. The longest phases are time from consultation to biopsy and from diagnosis to treatment. Improving multidisciplinary care coordination for vulnerable patient populations could improve the timeliness of suspicious lung nodule care. (JTCVS Open 2025;24:451-71)



Time intervals through lung nodule phases of care.

CENTRAL MESSAGE

Delays in suspicious lung nodule care are multifactorial and occur at all phases of care, with consultation to biopsy and diagnosis to treatment being the longest phases of care.

PERSPECTIVE

Timeliness of suspicious lung nodule care is associated with demographic, social, and clinical factors. Times from consultation to biopsy and diagnosis to treatment are the longest phases of lung nodule care. Expanding multidisciplinary care coordination might mitigate delays in suspicious lung nodule care, particularly for patients with a high degree of medical and social complexity.

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Abbreviations and Acronyms

- ADI = Area Deprivation Index
- BMI = body mass index
- CT = computed tomography
- ECOG = Eastern Cooperative Oncology Group
- IQR = interquartile range
- SBRT = stereotactic body radiotherapy
- TTD = time to diagnosis
- TTT = time to treatment
- UCM = University of Chicago Medicine

Lung cancer survival has benefited from improvements in staging, treatment options, and access to care.[1-6] Recently, time to diagnosis (TTD) and time to treatment (TTT) for patients presenting with non–small cell lung cancer have been increasing,[7,8] leading to higher mortality.[9-11] These delays have been associated with Black race, more recent year of diagnosis, nonprivate insurance, and diagnosis/treatment at different facilities regardless of disease stage.[7]

Precisely where delays in care occur from identification of suspicious lung nodules to treatment remains poorly characterized. We measure the time intervals associated with phases of care (nodule identification, referral, consultation with a lung cancer specialist, biopsy, diagnosis, and treatment) at an academic medical center serving a diverse, minoritized, and socially vulnerable study population. We also assess factors contributing to delays in each phase to identify ways to improve the timeliness of suspicious lung nodule care. We hypothesized that sociodemographic factors (higher age, Black race, widowed marital status) and clinical factors (underlying cardiovascular disease, a high degree of frailty) would be associated with increased time in each phase of lung cancer care before the initiation of this study. We also hypothesized that the longest phase of care would be the time from diagnosis to treatment.

MATERIAL AND METHODS

Study Design and Population

We conducted a retrospective single-institution study of patients evaluated for suspicious lung nodules at the University of Chicago Medicine (UCM) from August 2020 to August 2022. This study was approved by the University of Chicago Institutional Review Board (IRB22-1329, September 1, 2022).

Inclusion and Exclusion Criteria

Inclusion criteria were defined as evaluation and treatment for suspicious lung nodules or suspected clinical stage I or II lung cancer at UCM during the study period. Patients with suspicious lung nodules were identified using electronic medical record lists from the thoracic surgery and radiation oncology clinics at UCM. For patients identified via low-dose computed tomography (CT), suspicious nodules were those identified as Lung-RADS score of 4A, 4B, or 4X. For patients identified incidentally, suspicious nodules were defined as those at higher risk for malignancy due to morphology, growth, and size, and referred for further oncologic workup. Patients referred for treatment after diagnosis at outside hospitals were also included. Exclusion criteria included suspected stage III or IV disease and patients with nonprimary lung cancers (Figure E1).

Data Collection and Definitions

Electronic medical records were reviewed to collect dates for each phase of care, including date of lung nodule identification (Nodule ID), referral to lung cancer specialists (eg, pulmonologists, thoracic surgeons, or medical oncologists) for consultation (Referral), initial consultation appointment (Consultation), first diagnostic biopsy (Biopsy), pathology resulting from the first diagnostic biopsy (Diagnosis), and treatment initiation (Treatment). Nodules were characterized based on whether initial identification of the nodule led to immediate workup (High Risk) or surveillance imaging (Low Risk) as well as whether the nodule was identified via low-dose CT scan (Screening) or other imaging modalities (Incidental). The point at which the Low-Risk nodule required further workup was considered as the initial time point of entry into the study. For patients initially referred to specialists for further workup, but who were then advised to pursue additional surveillance imaging, only the referral for further oncologic workup (eg, via biopsy) was used as the Referral timepoint. This definition was applied for both Low-Risk and High-Risk nodules. TTD was defined as the difference in days between Referral and Diagnosis. TTT was defined as the difference in days between Referral and Treatment.

Patient demographic variables including age, self-reported race/ethnicity, gender, marital status, insurance status, body mass index (BMI), Eastern Cooperative Oncology Group (ECOG) performance status, frailty assessment by Fried's Frailty Phenotype,[12] medical comorbidities, type of consultant, smoking history, history of biopsies, lung nodule size, and clinical tumor staging, if applicable, were collected. Nodule size was defined as the largest diameter of the solid component at the time of Nodule ID. Nodule size was stratified by size as less than 20 mm and greater than or equal to 20 mm. A size of 20 mm was used to dichotomize nodule size per the 2023 American Association for Thoracic Surgery Expert Consensus Document regarding management of subsolid nodules, in which 20 mm is used as a threshold to guide management decision-making.[13] The National Area Deprivation Index (ADI) was determined by a patient's domicile using the Neighborhood Atlas by the Applied Population Lab at the University of Wisconsin- Madison.[14] The study population was stratified into quartiles based on national ADI percentile 0 to 25 (first quartile), 26 to 50 (second quartile), 51 to 75 (third quartile), and 76 to 100 (fourth quartile). Higher ADI quartiles represent increasing degrees of neighborhood deprivation. Time from the COVID-19 pandemic was calculated as time in days between March 11, 2020, and the time of referral for lung cancer workup. For multivariable Cox regressions, time from the COVID-19 pandemic to referral was grouped into before or after 1 year of the pandemic, consistent with prior research.[15,16] Straight-line distance between the patient's domicile and the University of Chicago's Center for Care and Discovery was calculated using Google Maps and grouped into less than 12.5 miles, 12.5 to 50 miles, and greater than 50 miles.[17,18] For this study, bronchoscopic biopsy was defined as any biopsy performed using bronchoscopy, such as endobronchial ultrasound with transbronchial needle aspiration. Surgical biopsy or treatment was defined as any video-assisted thoracoscopic surgery, robotic-assisted, or open surgery used to biopsy or resect suspicious lung nodules or cancer. Patients receiving surgical (wedge) biopsies were treated simultaneously; therefore, for these patients, times from referral to biopsy and TTT were the same. Subgroup analyses of TTD and TTT were performed in a cohort of patients excluding patients who received surgical biopsies. Cancer staging was defined using the American Joint Committee on Cancer Staging System, 8th edition.

Statistical Analysis

All statistical analyses were performed using R Statistical Software (version 4.2.2; R Foundation for Statistical Computing). Descriptive statistics were performed for categorical data. Chi-square tests were used to compare distributions of categorical variables between groups. Continuous data are presented as median (interquartile range [IQR]) for nonparametric data sets, and mean (SD) for parametric data. Univariable Cox proportional hazard regression was used to identify variables significantly associated with TTD and TTT. Multivariable Cox proportional hazard regressions were constructed using the most significant predictor variables from univariable Cox proportional regression modeling to identify variables impacting time to event when controlling for other significant predictors. Differences between groups were compared using the Wilcoxon rank-sum test and Kruskal–Wallis test for nonparametric continuous data. Dunn's test with Bonferroni correction was implemented if the Kruskal–Wallis test was rejected for nonparametric multiple group comparisons. Notably, in this analysis, a hazard ratio greater than 1.0 indicates a shorter time to event (ie, diagnosis or treatment), and a hazard ratio less than 1.0 indicates a longer time to event. Therefore, higher hazard ratios indicate variables associated with shorter TTD. We performed subgroup analyses to identify factors associated with increased time spent in each key phase of care.

RESULTS

Patient Cohort and Nodule Characteristics

A total of 157 patients were included in the study with a median age of 69.6 years (IQR, 64.8-74.5 years). Ninety-two patients were female (58.6%), and 83 patients identified as non-Hispanic Black race/ethnicity (52.9%). Most patients (118, 75.2%) were insured through Medicare (Table 1). Compared with Not Black patients, Black patients were more likely to be single/never married, to be insured through Medicare instead of private insurance, to be frail, to have a higher ECOG performance status, to live in a higher ADI quartile, to live within 12.5 miles of the hospital, to be current smokers, and to have a history of lung disease (Table 1).

Approximately half of the nodules were identified through screening (76, 48.4%), and the other half were incidental (81, 51.6%). Most lung nodules were biopsied bronchoscopically. Of 95 patients receiving bronchoscopic biopsy, 85 (89.5%) were diagnostic. Most lung nodules were adenocarcinoma (109, 79.6%), and 10.2% (16) were benign (Table 2). Most patients were referred to pulmonology (87, 55.8%) or thoracic surgery (59, 37.8%), with a minority of patients referred directly to medical oncology (10, 6.4%). Most nodules were less than 20 mm in size (88, 56%). Smaller nodules were more likely to be biopsied surgically rather than bronchoscopically (P = .009). Most nodules were treated initially with surgery (75, 51.7%) or stereotactic body radiotherapy (SBRT) (64, 44.1%). Most patients receiving SBRT also received invasive mediastinal staging via bronchoscopic biopsy before treatment (46, 72%). There were no statistically significant differences in rates of initial treatment between Black and Not Black patients, with 33 (43%) Black patients receiving surgery compared with 42 (62%) Not Black patients and 42 (55%) Black patients receiving SBRT compared with 22 (32%) Not Black patients (P = .10).

Median time intervals between Nodule ID, Referral, Consultation, Biopsy, and Diagnosis ranged from 0 to 34 days (Figure 1). The largest time intervals occurred from Consultation and Biopsy (median [IQR] 20 [12-34] days) and from Diagnosis to Treatment (median [IQR] 28 [4-43] days) (Table E1).

Factors Associated With Time From Nodule Identification to Referral

Median (IQR) time from Nodule ID to Referral was 4 (0-18) days (Figure 1). Univariable analysis showed that Medicaid insurance, referral to thoracic surgery, surgical biopsy, and High-Risk nodules were associated with longer time from nodule ID to referral (Table E2). Multivariable analysis showed that Medicaid insurance was associated with longer time from nodule ID to referral (Table 3).

Factors Associated With Time From Referral to Consultation

Median (IQR) time from Referral to Consultation was 7 (3-14) days (Figure 1). Univariable analysis showed that living less than 12.5 miles from the hospital, more than 1 year from the start of the COVID-19 pandemic to referral, and High-Risk nodules were associated with longer time from referral to consultation, and Black race was associated with shorter time from referral to consultation (Table E2). Multivariable analysis demonstrated that age less than 65 years and High-Risk nodules were associated with longer time from referral to consultation (Table 3).

Factors Associated With Time From Consultation to Biopsy

The median (IQR) time from Consultation to Biopsy was 20 (12-34) days (Figure 1). Univariable analysis showed that Black race, single marital status, Medicaid insurance, and surgical biopsy were associated with longer time from consultation to biopsy (Table E3). Multivariable analysis demonstrated that female gender, widowed marital status, and frailty were associated with longer time from consultation to biopsy, and living within 12.5 miles of the hospital, history of cardiovascular disease, and receipt of CT-guided biopsy were associated with shorter time from consultation to biopsy (Table 3).

Factors Associated With Time From Diagnosis to Treatment

The median (IQR) time from diagnosis to treatment was 28 (8 to 43) days (Figure 1). Univariable analysis demonstrated that age, race, insurance status, frailty, ECOG performance status, type of biopsy, time from the start of the COVID-19 pandemic to referral, and type of initial treatment were associated with time from diagnosis to treatment (Table E3). Multivariable analysis demonstrated that Medicaid insurance, cardiovascular disease, referral more

TABLE 1. Patient demographics and clinical characteristics

	All (n = 157)	Incidental (n = 81)	Screening (n = 76)	*P* value
Age (y) – median (IQR)	69.6 (64.8-74.5)	69.2 (64.5-75.4)	70.5 (65.5-74.4)	.75
Age – no. (%)				
<65 y	40 (25.5)	22 (27.2)	18 (23.7)	.33
≥65 y	117 (74.5)	59 (72.8)	58 (76.3)	
Gender – no. female (%)	92 (58.6)	48 (59.3)	44 (57.9)	.21
Race – no. (%)				
Black-identifying	83 (52.9)	39 (48.1)	44 (57.9)	.29
Not Black-identifying	74 (47.1)	42 (51.9)	32 (42.1)	
Marital status – no. (%)				
Married	72 (45.9)	34 (42.0)	38 (50.0)	.71
Divorced	12 (7.6)	8 (9.9)	4 (5.3)	
Single/never married	43 (27.4)	23 (28.4)	20 (26.3)	
Separated	4 (2.5)	2 (2.5)	2 (2.6)	
Widow/widower	25 (15.9)	14 (17.3)	11 (14.5)	
Unknown	1 (0.6)	0 (0.0)	1 (1.3)	
Insurance status – no. (%)				
Private	27 (17.2)	12 (14.8)	15 (19.7)	.42
Medicare	118 (75.2)	61 (75.3)	57 (75.0)	
Medicaid	10 (6.4)	7 (8.6)	3 (3.9)	
None	2 (1.3)	1 (1.2)	1 (1.3)	
BMI (kg/m^2) – median (IQR)	27.2 (22.7-30.2)	25.8 (21.5-29.7)	27.7 (23.8-31.4)	.06
BMI category – no. (%)				
Normal (18.5-24.9)	48 (30.6)	26 (32.1)	22 (28.9)	.30
Underweight (<18.5)	12 (7.6)	9 (11.1)	3 (3.9)	
Overweight (25-29.9)	54 (34.4)	27 (33.3)	27 (35.5)	
Obese (≥30)	43 (27.4)	19 (23.5)	24 (31.6)	
Frailty assessment – no. (%)				
Not frail	45 (28.7)	16 (19.8)	29 (38.2)	.08
Prefrail	26 (16.6)	15 (18.5)	11 (14.5)	
Frail	31 (19.7)	18 (22.2)	13 (17.1)	
Not assessed	55 (35.0)	32 (39.5)	23 (30.3)	
ECOG performance status – no. (%)				
0	43 (27.4)	23 (28.4)	20 (26.3)	.21
1	76 (48.4)	34 (42.0)	42 (55.3)	
2	24 (15.3)	16 (19.8)	8 (10.5)	
3	3 (1.9)	2 (2.5)	1 (1.3)	
4	2 (1.3)	2 (2.5)	0 (0.0)	
Unknown/not documented	9 (5.7)	4 (4.9)	5 (6.6)	
ADI national percentile – median (IQR)	57.0 (34.0-73.0)	56.0 (31.0-75.0)	57.0 (36.5-70.0)	.84
ADI quartile – no (%)				
First quartile (least deprived)	19 (12.1)	13 (16.0)	6 (7.9)	.22
Second quartile	41 (26.1)	19 (23.5)	22 (28.9)	
Third quartile	61 (38.9)	28 (34.6)	33 (43.4)	
Fourth quartile (most deprived)	35 (22.3)	21 (25.9)	14 (18.4)	
Unknown	1 (0.6)	0 (0.0)	1 (1.3)	
Distance to hospital – no (%)				
<12.5 miles	79 (52.3)	35 (45.5)	44 (59.5)	.22
12.5-49.9 miles	61 (40.4)	36 (46.8)	25 (33.8)	
≥50 miles	11 (7.3)		6 (7.8)	
Time from start of COVID-19 pandemic to referral				
<1 y	61 (38.9)	33 (40.7)	28 (36.8)	.74
≥1 y	96 (61.1)	48 (59.3)	48 (63.2)	

(Continued)

TABLE 1. Continued

	All (n = 157)	Incidental (n = 81)	Screening (n = 76)	*P* value
Smoking history (%)				
Never smoker	17 (11.0)	13 (16.0)	4 (5.3)	**.003**
Former smoker	82 (52.9)	48 (59.3)	34 (44.7)	
Current smoker	56 (36.1)	20 (24.7)	36 (47.4)	
Pack-years if former or current smoker – median (IQR)	40.0 (20.0-51.4)	40.0 (18.8-52.9)	42.0 (27.6-50.2)	.14
Comorbidities – no. (%)				
Cardiovascular disease	97 (61.8)	49 (60.5)	48 (63.2)	.86
Lung disease	70 (44.6)	40 (49.4)	30 (39.5)	.28
Diabetes mellitus	31 (19.7)	13 (16.0)	18 (23.7)	.32
History of cancer	61 (38.9)	29 (35.8)	32 (42.1)	.52

Statistically significant comparisons are bolded. *IQR*, Interquartile range; *BMI*, body mass index; *ECOG*, Eastern Cooperative Oncology Group; *ADI*, Area Deprivation Index.

than 1 year from the start of COVID-19, and initial treatment with SBRT were associated with longer time from diagnosis to treatment, and single/never married marital status, BMI less than 18.5, and surgical biopsy were associated with shorter time from diagnosis to treatment (Table 3).

Factors Associated With Time From Referral to Diagnosis

Median (IQR) TTD was 34 (22-56) days (Figure 1). Univariable analysis showed that Black race, single or widowed marital status, and surgical biopsy were associated with increased TTD (Table E4). Multivariable analysis showed that Black race, widowed marital status, and referral more than 1 year from the start of COVID-19 were associated with longer TTD (Table 4). Smoking status was not associated with TTD.

Factors Associated With Time From Referral to Treatment

Median (IQR) TTT was 65 (44 to 84) days (Figure 1). Univariable analysis showed that Black race, single or widowed marital status, Medicaid or Medicare insurance, overweight BMI, ECOG performance status of 2, fourth ADI quartile, and bronchoscopic biopsy were associated with increased TTT (Table E4). Multivariable analysis demonstrated that female gender, widowed marital status, frailty, fourth ADI quartile, referral more than 1 year from the start of COVID-19, and initial treatment with SBRT were associated with longer TTT, and BMI less than 18.5, ECOG performance status of 2 or higher, surgical biopsy, history of cancer, and initial treatment with neoadjuvant therapy were associated with shortened TTT (Table 4). Smoking status was not associated with TTT.

Impact of Key Sociodemographic and Clinical Factors on Time Spent in Phases of Care

Median (IQR) time from nodule ID to referral for patients referred to thoracic surgery was 6 (1-23) days compared with 3 (0-11) days for patients referred to pulmonology and 2 (0-31) days for patients referred to medical oncology (Table E2). Median (IQR) time from referral to consultation was 7 (3-15) days for patients referred to pulmonology compared with 7 (2-12) for patients referred to thoracic surgeons (Table E3). Type of consultant was not associated with increased TTD or TTT (Table E4).

Median (IQR) time from nodule ID to referral was 3 (0-25) days for patients with nodules less than 20 mm compared with 5 (1-11) for those with nodules 20 mm or greater. There were also no differences in TTD or TTT between patients with nodules less than 20 mm and 20 mm or greater (TTD 36 [26-55] vs 32 [19-56] days; TTT 66 [43-82] vs 62 [45-88] days, Table E4).

Median (IQR) TTD and TTT were longer for Black patients compared with Not Black patients (TTD 41 [26-69] vs 30 [19-44] days, $P < .001$; TTT 72 [54-96] vs 49 [36-77] days, $P < .001$, Table E4). Median (IQR) time from diagnosis to treatment was 36 (25-48) days for patients receiving bronchoscopic biopsy, resulting in median (IQR) TTT of 73 (52-88) days for patients receiving bronchoscopic biopsy compared with 43 (29-66) days for patients receiving no bronchoscopic biopsy ($P < .001$, Table E4). Median (IQR) TTT for patients receiving SBRT was 76 (63-90) compared with 51 (38-80) for patients receiving surgery. Patients receiving SBRT had a median (IQR) time from diagnosis to treatment of 41 (31-50) days.

Impact of COVID-19 on Time Spent During Each Phase of Care

To determine whether the COVID-19 pandemic affected the timeliness of care delivered, we included referral greater than 1 year after the start of the COVID-19 pandemic as a covariate. We found that referral more than 1 year from the start of the COVID-19 pandemic was associated with longer TTD, TTT, and time from diagnosis to treatment in multivariable analysis (Tables 3 and 4).

TABLE 2. Nodule diagnosis and treatment characteristics

	All (n = 157)	Incidental (n = 81)	Screening (n = 76)	*P* value
Consulting party – no (%)				
Pulmonology	87 (55.8)	52 (59.8)	35 (40.2)	.83
Thoracic surgery	59 (37.8)	34 (57.6)	25 (42.4)	
Medical oncology	10 (6.4)	5 (50.0)	5 (50.0)	
Type of biopsy – no. (%)				
Bronchoscopic	95 (60.5)	53 (65.4)	42 (55.3)	.30
Surgical	41 (26.1)	17 (21.0)	24 (31.6)	
CT-guided needle biopsy	7 (4.5)	4 (4.9)	3 (3.9)	
No definitive biopsy/other	14 (8.9)	7 (8.6)	7 (9.2)	
Nodule size* – no (%)				
<20 mm	88 (56.4)	44 (54.3)	44 (57.9)	.70
≥20 mm	68 (43.6)	37 (45.7)	31 (42.1)	
Benign nodule on biopsy – no. (%)	16 (10.2)	4 (4.9)	12 (15.8)	.15
High-risk nodules†	92 (58.6)	56 (69.1)	36 (47.4)	**.009**
First-line therapy‡ – no. (%)				
Definitive chemotherapy	2 (1.4)	1 (1.2)	1 (1.3)	.61
Neoadjuvant therapy§ (chemo/RT or chemo/IO)	4 (2.8)	1 (1.2)	3 (3.9)	
Surgery	75 (51.7)	37 (45.7)	38 (50.0)	
SBRT	64 (44.1)	36 (44.4)	28 (36.8)	
AJCC lung cancer stage (clinical)‖ – no. (%)				
IA	97 (68.8)	47 (64.4)	50 (73.5)	.96
IB	19 (13.4)	11 (15.1)	8 (11.8)	
IIA	6 (4.3)	4 (5.5)	2 (2.9)	
IIB	19 (13.4)	11 (15.1)	8 (11.8)	
Histology of tumor – no. (%)				.50
Small-cell lung cancer	3 (2.2)	1 (1.2)	2 (2.6)	
Adenocarcinoma	109 (79.6)	57 (70.4)	52 (68.4)	
Squamous cell carcinoma	21 (15.3)	14 (17.3)	7 (9.2)	
Carcinoid tumor	3 (2.2)	2 (2.5)	1 (1.3)	
Mesothelioma	1 (0.7)	1 (1.2)	0 (0.0)	

Statistically significant comparisons are bolded. *CT*, Computed tomography; *Chemo/RT*, chemotherapy and radiotherapy; *Chemo/IO*, chemotherapy and immunotherapy; *SBRT*, stereotactic body radiotherapy; *AJCC*, American Joint Committee on Cancer. *Percentages represent 156 patients with nodule size information available. †Nodules were characterized based on whether initial identification of the nodule led to immediate workup (High Risk) or surveillance imaging (Low Risk) as well as whether the nodule was identified via low-dose CT scan (Screening) or other imaging modalities (Incidental). ‡Percentages represent 145 patients with available treatment records. §Neoadjuvant therapy includes chemotherapy with immunotherapy or radiotherapy. ‖Of 157 patients, 16 did not have clinical staging information due to having benign lung nodules. Therefore, percentages shown for American Joint Committee on Cancer clinical stage represent the 141 patients for whom full staging information was available.

Factors Associated With Time to Diagnosis, Excluding Surgical Biopsies

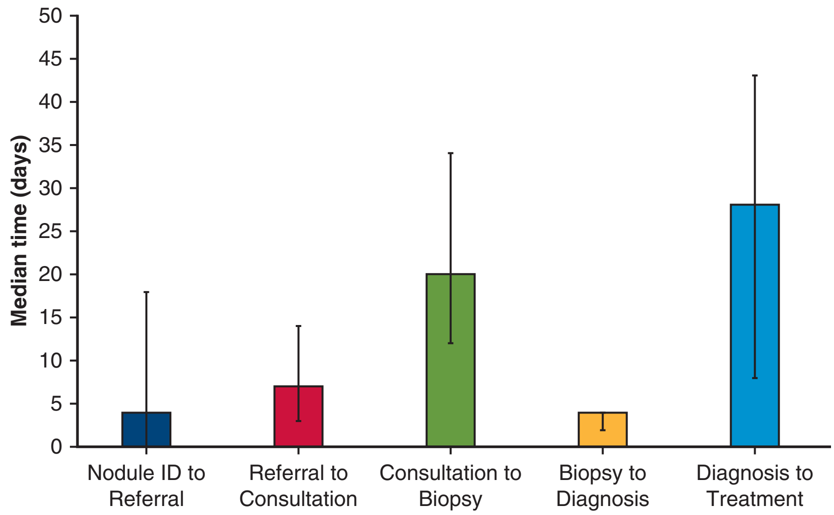
For a total of 116 patients receiving nonsurgical biopsies, median (IQR) TTD was 31 (19-50) days. Multivariable analysis showed that widowed marital status and referral more than 1 year from the start of COVID-19 were associated with longer TTD (Table E5).

Factors Associated With Time to Treatment, Excluding Surgical Biopsies

Median (IQR) TTT was 72 (51-88) days in the nonsurgical biopsy subgroup. Multivariable analysis demonstrated divorced marital status, widowed marital status, Medicaid insurance, and initial treatment with SBRT were associated with longer TTT, whereas initial treatment with neoadjuvant therapy was associated with shorter TTT (Table E5).

DISCUSSION

We characterized the time spent in phases of suspicious lung nodule care and identified factors associated with increased time spent in each phase of care. The longest phases of care during TTD and TTT were time from consultation to biopsy and from diagnosis to treatment. Factors in multiple domains, including demographic (age, race, gender, marital status), social (residential area, insurance status), and clinical (type of lung nodule, cardiovascular disease, frailty, BMI, ECOG, type of biopsy and initial treatment), were associated with longer time intervals (Figures 2 and 3).



Time Interval	Median (IQR), days
Nodule ID to Referral	4 (0–18)
Referral to Consultation	7 (3–14)
Consultation to Biopsy	20 (12–34)
Biopsy to Diagnosis	4 (2–4)
Diagnosis to Treatment	28 (8–43)

FIGURE 1. Key time intervals throughout lung nodule phases of care. Error bars represent IQR. *IQR*, Interquartile range.

Our findings are consistent with previous work highlighting the impact of race/ethnicity, area deprivation, gender, spousal support, and insurance status on disparities in lung cancer care. Compared with White patients, racial and ethnic minority patients experience longer wait times from nodule ID to referral for lung cancer surgery as well as from diagnosis to treatment.[19,20] Residential area deprivation is a highly negative social determinant of health associated with higher lung cancer–specific mortality and more individual-level barriers to care due to cost.[21,22] Female patients are more likely to delay care due to factors such as inability to take time off work or lack of alternatives for childcare or caregiving responsibilities.[23,24] Lack of spousal support is associated with social isolation, loneliness, and decreased likelihood of seeking treatment.[25-28] Patients with Medicaid have greater difficulty scheduling specialist appointments than patients with private insurance.[29] These delays may be the reason why there is no difference in survival between patients with Medicaid and uninsured patients, most prominently in states where Medicaid has not been expanded.[30,31]

The negative impact of these sociodemographic factors could be mitigated through heightened awareness and systemic change. One solution might include leveraging the expertise of an advanced practice provider to oversee the patient journey and facilitate multidisciplinary care coordination, particularly for the most isolated and vulnerable patients.[32,33] Multidisciplinary tumor boards, for example, expedite care by reducing unnecessary hospital and provider visits.[34] An additional solution might be increased investment in impoverished neighborhoods and expansion of educational infrastructure regarding health disparities, improving awareness of disease processes and treatment availability within these communities.[35] Finally, interventions such as a real-time registry with automated alerts to track delays as well as an antiracism curriculum for providers could reduce barriers for accessing care.[36] In the recent Accountability for Cancer Care through Undoing Racism and Equity trial, these interventions improved survival for patients with lung cancer.[37] Adopting these same interventions early in the diagnostic process for patients with suspicious lung nodules could minimize delays in care and improve patient outcomes by breaking down systemic barriers to care for all patients, regardless of race or background. Qualitative analyses to understand how to minimize delays is an appropriate next step from our present study.

In addition to sociodemographic factors, multiple clinical factors affected the timeliness of lung cancer care. Some findings were expected: Patients receiving bronchoscopic biopsy had longer TTT and time from diagnosis to treatment because patients receiving surgical (wedge) biopsies were

TABLE 3. Factors associated with each phase of care from referral to treatment in multivariable Cox regression analysis

Variable	Nodule ID to referral HR (95% CI)	Nodule ID to referral *P* value	Referral to consultation HR (95% CI)	Referral to consultation *P* value	Consultation to biopsy HR (95% CI)	Consultation to biopsy *P* value	Diagnosis to treatment HR (95% CI)	Diagnosis to treatment *P* value
Age								
<65 y	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
≥65 y	0.89 (0.32-2.53)	.83	4.13 (1.51-11.33)	**.006**	1.02 (0.45-2.35)	.96	0.84 (0.29-2.40)	.74
Gender – female vs male	0.72 (0.35-1.50)	.38	0.62 (0.34-1.13)	.12	0.46 (0.23-0.90)	**.02**	1.56 (0.80-3.03)	.19
Not Black vs Black race	0.54 (0.20-1.44)	.22	1.08 (0.36-3.22)	.90	1.83 (0.79-4.20)	.16	1.80 (0.56-5.75)	.32
Marital status								
Married	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Divorced	0.79 (0.24-2.60)	.70	1.95 (0.62-6.15)	.25	1.06 (0.41-2.75)	.90	0.43 (0.08-2.29)	.32
Single/never married	0.81 (0.36-1.80)	.60	1.41 (0.62-3.22)	.41	0.81 (0.35-1.87)	.62	4.27 (1.69-10.82)	**.002**
Widowed	1.43 (0.58-3.50)	.44	0.73 (0.30-1.76)	.48	0.31 (0.13-0.72)	**.007**	1.11 (0.39-3.19)	.84
Insurance status								
Private	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Medicare	1.37 (0.38-4.85)	.63	0.49 (0.14-1.70)	.26	1.00 (0.35-2.88)	.99	0.54 (0.12-2.34)	.41
Medicaid	0.17 (0.03-0.83)	**.03**	0.55 (0.13-2.32)	.41	0.32 (0.08-1.32)	.12	0.05 (0.01-0.39)	**.004**
BMI category (kg/m^2)								
Normal (18.5-24.9)	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Underweight (<18.5)	1.67 (0.50-5.59)	.40	2.30 (0.76-6.96)	.14	0.29 (0.08-1.10)	.07	4.12 (1.10-15.47)	**.04**
Overweight (25-29.9)	0.88 (0.41-1.89)	.74	0.90 (0.45-1.80)	.77	1.01 (0.49-2.07)	.98	1.26 (0.56-2.82)	.58
Obese (≥30)	1.99 (0.92-4.30)	.08	1.12 (0.52-2.41)	.77	0.78 (0.36-1.73)	.55	0.96 (0.43-2.16)	.93
Frailty assessment								
Not frail	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Prefrail	0.93 (0.42-2.10)	.87	1.92 (0.94-3.90)	.07	1.23 (0.62-2.46)	.55	1.05 (0.48-2.31)	.90
Frail	1.53 (0.58-4.02)	.39	1.03 (0.42-2.52)	.95	0.34 (0.15-0.77)	**.009**	0.86 (0.32-2.30)	.77
ECOG performance status								
0	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
1	1.02 (0.45-2.31)	.97	0.58 (0.27-1.23)	.16	–	–	1.55 (0.63-3.83)	.95
2	1.10 (0.32-3.74)	.88	1.04 (0.32-3.35)	.95	–	–	0.55 (0.14-2.24)	.41
3	2.11 (0.29-15.04)	.46	3.65 (0.57-23.29)	.17	–	–	0.69 (0.10-5.04)	.72
ADI quartile								
First quartile (least deprived)	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Second quartile	0.72 (0.25-2.10)	.55	1.76 (0.67-4.61)	.25	1.90 (0.75-4.79)	.18	0.45 (0.15-1.39)	.17
Third quartile	1.15 (0.33-4.04)	.82	1.76 (0.50-6.20)	.38	0.67 (0.26-1.73)	.41	1.39 (0.37-5.23)	.63
Fourth quartile (most deprived)	0.50 (0.14-1.76)	.28	1.24 (0.33-4.66)	.75	2.36 (0.85-6.55)	.10	0.64 (0.16-2.61)	.54
Type of biopsy performed								
Bronchoscopic	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Surgical	1.20 (0.62-2.32)	.59	1.57 (0.86-2.89)	.14	0.53 (0.26-1.05)	.07	14.10 (5.14-38.64)	<**.001**
CT-guided biopsy	0.92 (0.23-3.70)	.90	1.56 (0.33-7.37)	.59	5.78 (1.09-30.75)	**.04**	0.25 (0.05-1.15)	.08
Distance to hospital (miles)								
12.5-49.9 miles	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
<12.5 miles	0.63 (0.28-1.42)	.27	0.41 (0.14-1.19)	.10	2.27 (1.05-4.91)	**.04**	0.59 (0.23-1.53)	.28
≥50 miles	0.68 (0.22-2.10)	.50	1.61 (0.52-4.96)	.41	1.90 (0.68-5.35)	.22	0.24 (0.06-1.02)	.05
Time from start of COVID-19 pandemic to referral								
<1 y	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
≥1 y	1.88 (0.93-3.80)	.08	0.60 (0.31-1.15)	.12	0.66 (0.34-1.27)	.21	0.38 (0.19-0.77)	**.007**
Comorbidities								
Cardiovascular disease	–	–	–	–	2.56 (1.14-5.72)	**.02**	0.29 (0.14-0.59)	**.001**
Lung disease	–	–	–	–	–	–	–	–
Diabetes mellitus	–	–	–	–	–	–	–	–
History of cancer	–	–	–	–	1.69 (0.88-3.26)	.11	–	–

(Continued)

TABLE 3. Continued

Variable	Nodule ID to referral HR (95% CI)	Nodule ID to referral P value	Referral to consultation HR (95% CI)	Referral to consultation P value	Consultation to biopsy HR (95% CI)	Consultation to biopsy P value	Diagnosis to treatment HR (95% CI)	Diagnosis to treatment P value
Initial treatment								
Surgery	–	–	–	–	–	–	Ref	Ref
Neoadjuvant therapy*	–	–	–	–	–	–	1.96 (0.41-9.30)	.40
SBRT	–	–	–	–	–	–	0.35 (0.14-0.89)	**.03**
Nodule – low risk vs high risk	1.18 (0.66-2.14)	.57	2.10 (1.23-3.58)	**.007**	–	–	–	–

Statistically significant comparisons are bolded. *HR*, Hazard ratio; *BMI*, body mass index; *ECOG*, Eastern Cooperative Oncology Group; *ADI*, Area Deprivation Index; *CT*, computed tomography; *SBRT*, stereotactic body radiotherapy. *Neoadjuvant therapy includes chemotherapy with immunotherapy or radiotherapy.

biopsied and treated simultaneously. Subgroup analysis excluding patients who received surgical biopsies did not significantly affect our results. Other patient-specific clinical factors may reflect the underlying complexity of diagnostic decision-making and treatment planning. For example, patients with frailty, low BMI (BMI <18.5), poor functional status (ECOG of 2 or higher), or cardiovascular disease may require additional optimization to minimize treatment-related morbidity, increasing TTT.[15,38-40] A limitation of our study is that we did not collect data on specific proportions of patients requiring additional appointments for optimization. Patients receiving SBRT as initial treatment had longer TTT, consistent with previous data,[7] which might reflect the need for additional visits with providers not involved in the diagnostic process. In our cohort, most patients receiving SBRT had invasive mediastinal staging via endobronchial ultrasound with transbronchial needle aspiration. We found no significant difference in TTT between patients receiving both invasive mediastinal staging and SBRT compared with SBRT alone. It is possible our study may not be powered to detect an increase in TTT due to the additional staging procedure among patients receiving radiation.

We found that patients with High-Risk nodules had longer time from referral to consultation. Although this is counterintuitive, one hypothesis is that patients with High-Risk nodules could be new referrals to our medical system or to our group and therefore less likely to be connected with Consultation appointments in as timely a manner compared with patients with Low-Risk nodules, who were already known to our group through surveillance imaging. This suggests a need for expanding outreach and education for early referral and expediting scheduling for patients with newly identified High-Risk nodules. Despite our finding that many clinical factors were associated with longer TTT in our cohort, the median time from diagnosis to treatment was 28 days, well under the 90-day threshold suggested by recent studies as a benchmark for delays in lung cancer treatment.[34] Several aspects of our program could be contributing to this, including institutional culture and patient-, provider-, and system-level factors. For example, our institution discusses lung cancer cases at a weekly multidisciplinary tumor board integrating input from pulmonologists, medical oncologists, radiation oncologists, thoracic surgeons, and patient care navigators. Eligible patients are actively recruited into our robust lung cancer screening program headed by advanced practice providers. These factors likely improve the efficiency of care delivery for our patient population.

Given that our study period overlapped with the COVID-19 pandemic, when the American College of Surgeons and Thoracic Surgery Outcomes Research Network recommended a 3-month deferral period for treating lung nodules less than 2 cm in diameter,[41] we included time from the start of the pandemic to referral as a covariable in our multivariable regression models. Referral more than 1 year after the start of the COVID-19 pandemic was associated with longer TTT compared with referral within 1 year of the start of the pandemic. Dolan and colleagues[42] reported in 2022 that at a high-volume academic center, the first several months of the COVID-19 pandemic did not impact surgical wait time, tumor size, or postoperative complications for lung cancer surgery but did result in lower case volumes. However, to our surprise, case and clinic visit volumes were stable at our institution over our study period. This suggests that shorter TTT in the first year of the pandemic is due to factors other than overall volume. It is possible that changes in hospital infrastructure such as increased use of telemedicine visits could have enabled more timely treatment of patients who were referred within the first year of the pandemic, reducing scheduling difficulties and logistical barriers for accessing care after referral.[37,43] Other changes in infrastructure toward the start of the pandemic, such as prioritization of cancer care over other diseases, may be accounting for our findings.[44]

Limitations

This study has several limitations. First, data were collected retrospectively and causal inferences cannot be made. Second, this is a single-center study with a limited

TABLE 4. Factors associated with time to diagnosis and treatment in multivariable Cox regression analysis

Variable	TTD HR (95% CI)	TTD *P* value	TTT HR (95% CI)	TTT *P* value
Age				
<65 y	Ref	Ref	Ref	Ref
≥65 y	1.81 (0.77-4.30)	.18	1.34 (0.54-3.31)	.53
Gender – female vs male	0.50 (0.24-1.01)	.06	0.41 (0.19-0.90)	**.03**
Not Black vs Black race	2.91 (1.10-7.72)	**.03**	2.40 (0.72-8.00)	.15
Marital status				
Married	Ref	Ref	Ref	Ref
Divorced	1.30 (0.52-3.22)	.57	0.64 (0.16-2.63)	.54
Single/Never married	0.52 (0.23-1.16)	.11	0.95 (0.37-2.44)	.91
Widowed	0.24 (0.10-0.60)	**.002**	0.15 (0.04-0.48)	**.001**
Insurance status				
Private	Ref	Ref	Ref	Ref
Medicare	1.04 (0.30-3.63)	.96	1.01 (0.21-4.85)	.99
Medicaid	0.67 (0.14-3.12)	.61	0.69 (0.13-3.79)	.67
BMI category (kg/m^2)				
Normal (18.5-24.9)	Ref	Ref	Ref	Ref
Underweight (<18.5)	2.07 (0.55-7.79)	.28	9.95 (2.20-45.07)	**.003**
Overweight (25-29.9)	1.17 (0.53-2.58)	.70	1.76 (0.72-4.34)	.22
Obese (≥30)	1.30 (0.62-2.77)	.49	0.95 (0.40-2.25)	.91
Frailty assessment				
Not frail	Ref	Ref	Ref	Ref
Prefrail	1.30 (0.68-2.48)	.43	0.73 (0.34-1.60)	.43
Frail	1.03 (0.51-2.08)	.93	0.20 (0.07-0.62)	**.005**
ECOG performance status				
0	Ref	Ref	Ref	Ref
1	–	–	0.97 (0.39-2.42)	.95
2	–	–	10.23 (2.32-45.17)	**.002**
3	–	–	15.39 (1.68-141.16)	**.02**
ADI quartile				
First quartile (least deprived)	Ref	Ref	Ref	Ref
Second quartile	1.54 (0.64-3.70)	.34	1.15 (0.35-3.79)	.82
Third quartile	1.47 (0.58-3.70)	.42	0.24 (0.05-1.04)	.06
Fourth quartile (most deprived)	1.81 (0.66-4.94)	.25	0.15 (0.03-0.68)	**.01**
Type of biopsy performed				
Bronchoscopic	Ref	Ref	Ref	Ref
Surgical	0.65 (0.32-1.30)	.22	9.01 (3.58-22.69)	**<.001**
CT-guided biopsy	1.40 (0.21-9.23)	.73	3.33 (0.53-20.82)	.20
Smoking history				
Never smoker	Ref	Ref	Ref	Ref
Former smoker	–	–	1.16 (0.40-3.40)	.78
Current smoker	–	–	0.49 (0.16-1.52)	.22
Distance to hospital (miles)				
12.5-49.9 miles	Ref	Ref	Ref	Ref
<12.5 miles	0.98 (0.42-2.26)	.96	1.54 (0.64-3.74)	.34
≥50 miles	1.13 (0.39-3.24)	.82	1.84 (0.53-6.45)	.34
Time from start of COVID-19 pandemic to referral				
<1 y	Ref	Ref	Ref	Ref
≥1 y	0.46 (0.24-0.91)	**.02**	0.44 (0.19-0.99)	**.048**
Comorbidities				
Cardiovascular disease	1.65 (0.79-3.47)	.18	0.98 (0.42-2.29)	.96
Lung disease	–	–	–	–

(Continued)

TABLE 4. Continued

Variable	TTD		TTT	
	HR (95% CI)	*P* value	HR (95% CI)	*P* value
Diabetes mellitus	–	–	–	–
History of cancer	–	–	2.32 (1.13-4.77)	**.02**
Initial treatment				
Surgery	–	–	Ref	Ref
Neoadjuvant therapy*	–	–	7.80 (1.65-37.00)	**.01**
SBRT	–	–	0.18 (0.07-0.45)	**<.001**

Statistically significant comparisons are bolded. *TTD*, Time to diagnosis; *TTT*, time to treatment; *HR*, hazard ratio; *BMI*, body mass index; *ECOG*, Eastern Cooperative Oncology Group; *ADI*, Area Deprivation Index; *CT*, computed tomography; *SBRT*, stereotactic body radiotherapy. *Neoadjuvant therapy includes chemotherapy with immunotherapy or radiotherapy.

study period focused on an academic medical center in the South Side of Chicago, and our findings may have limited generalizability to other centers including academic centers outside of the United States. We identified patients using lists from thoracic surgery and radiation oncology clinics, which may have introduced selection bias; however, these clinics at our institution provide the majority of early-stage lung cancer treatment. This selection bias may be accentuated by our exclusion of patients who were lost to follow-up, yielding a patient cohort who may have a higher baseline ability to navigate the healthcare system than the true patient population at any given medical center. The number of CT-guided biopsies in our study was low, which may not accurately reflect workflows in the general population and may miss delay associated with scheduling with interventional radiology colleagues. We were unable to accurately measure how many patients were evaluated for lung nodules (eg, by other specialists included pulmonology and medical oncology) without receiving treatment. Therefore, another potential source of selection bias is that we chose to limit the scope of our analysis to patients undergoing treatment. Additionally, we did not collect data on respiratory status or individual COVID-19 status of each patient in our study, limiting our ability to describe the impact of presenting symptoms or individual COVID-19 positivity on TTD or TTT. We did not collect survival outcomes in this study, limiting our ability to describe the impact of delays in care on oncologic outcomes. Finally, our study focuses on phases of care beginning from nodule ID at the tertiary care level. Therefore, we are unable to derive inferences regarding the impact of social determinants of health on access to care before nodule ID. Despite

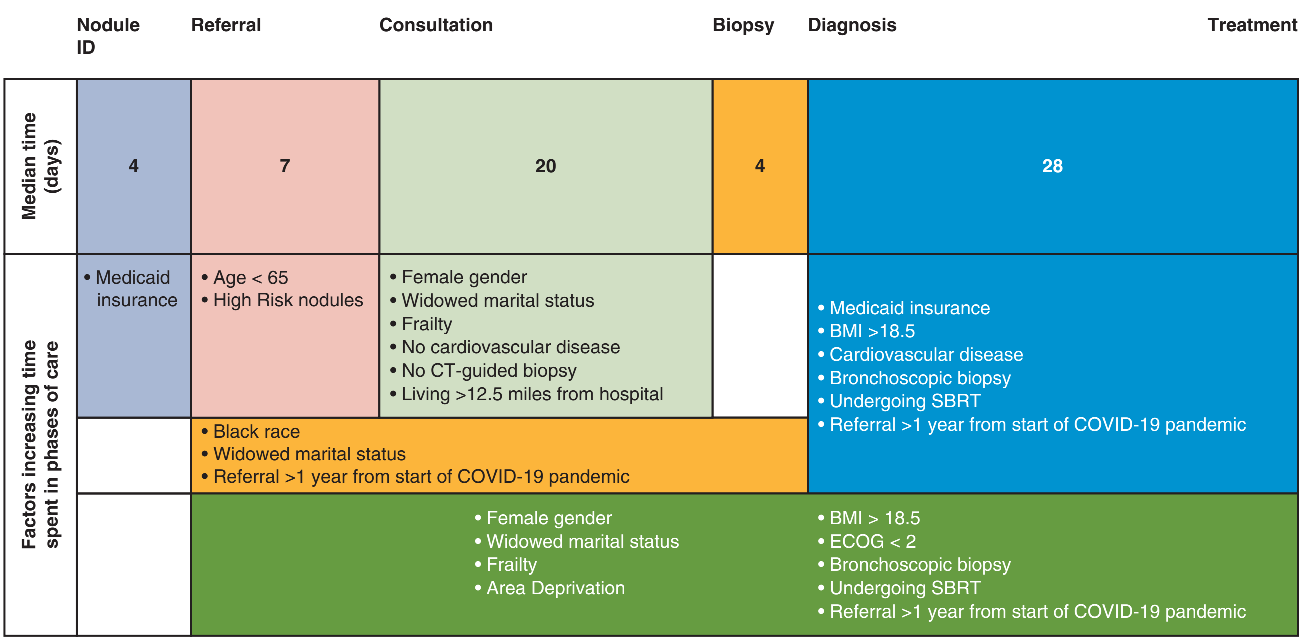


FIGURE 2. Factors associated with time intervals through lung nodule phases of care. Numbers in top row represent median time spent during each phase of care in days. *CT*, Computed tomography; *BMI*, body mass index; *SBRT*, stereotactic body radiotherapy; *ECOG*, Eastern Cooperative Oncology Group.

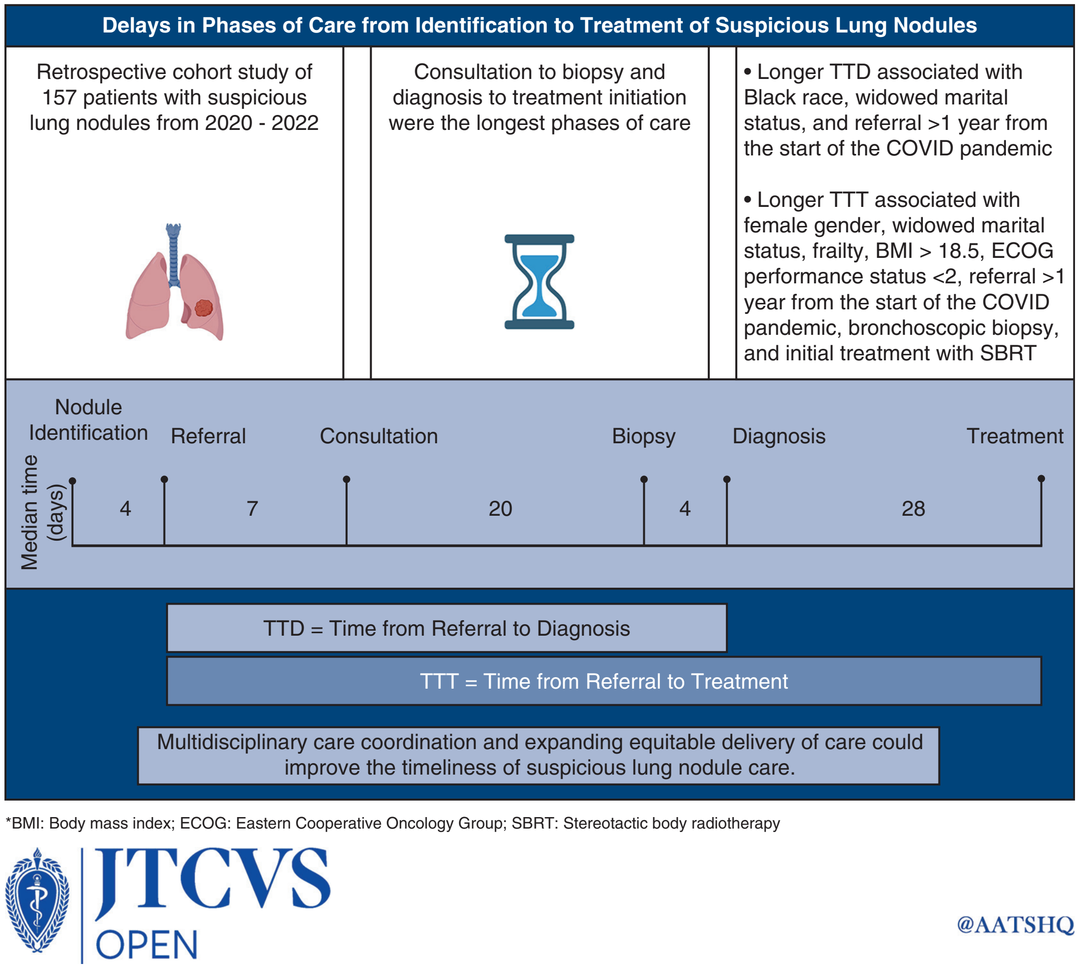


FIGURE 3. Graphical Abstract.

these limitations, our findings remain useful for decision-making regarding system-level changes to improve the timeliness of care for patients, especially those who are most vulnerable, with suspicious lung nodules.

CONCLUSIONS

Increased time spent in suspicious lung nodule care is associated with demographic, social, and clinical factors. The longest phases of care are time from consultation to biopsy and from diagnosis to treatment. The timeliness of care for patients with suspicious lung nodules can be improved by facilitating multidisciplinary care coordination via expanded access to advanced practice providers, multidisciplinary tumor boards, and a real-time registry to track delays in care. Such initiatives will improve efficiency and reduce excess during steps necessitating complex decision-making (eg, treatment planning after diagnosis). Finally, system-level efforts should focus on improving equitable delivery of care to our most demographically and socially vulnerable patients because these patients experience the greatest delays in suspicious lung nodule care.

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: delays in care, lung cancer, phases of care, racial disparities, thoracic surgery

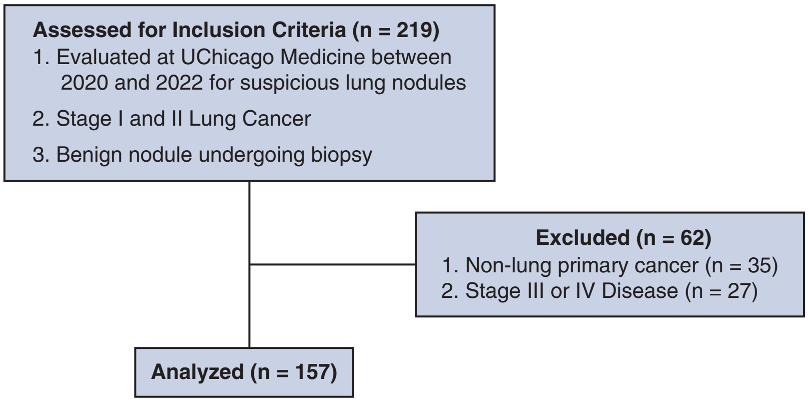

FIGURE E1. CONSORT diagram representing inclusion and exclusion criteria for cohort.

TABLE E1. All intervals throughout lung nodule phases of care

Time interval	Median (IQR), d
Nodule ID to referral	4 (0-18)
Nodule ID to consultation	15 (7-31)
Nodule ID to biopsy	41 (25-65)
Nodule ID to diagnosis	44 (28-69)
Nodule ID to treatment	73 (57-103)
Referral to consultation	7 (3-14)
Referral to biopsy	29 (20-49)
Referral to diagnosis	34 (22-56)
Referral to treatment	65 (44-84)
Consultation to biopsy	20 (12-34)
Biopsy to diagnosis	4 (2-4)
Diagnosis to treatment	28 (8-43)

IQR, Interquartile range.

TABLE E2. Univariable analysis for time from nodule identification to referral and referral to consultation

Variable	Nodule ID to referral		Referral to consultation	
	Median (IQR), d	*P* value	Median (IQR), d	*P* value
Age				
<65 y	5 (0-21)	Ref	7 (3-13)	Ref
≥65 y	4 (0-16)	.57	7 (3-14)	.50
Gender				
Female	5 (1-21)	Ref	7 (2-12)	Ref
Male	3 (0-12)	.25	7 (3-15)	.66
Race				
Not Black	6 (1-22)	Ref	9 (3-15)	Ref
Black	2 (0-11)	.51	6 (2-11)	**.01**
Marital status				
Married	4 (0-18)	Ref	6 (2-12)	Ref
Divorced	12 (1-21)	.98	7 (4-10)	.38
Single/never married	5 (0-12)	.76	10 (4-15)	.05
Widowed	3 (1-15)	.49	7 (3-15)	.25
Insurance status				
Private	6 (1-17)	Ref	5 (2-8)	Ref
Medicare	2 (0-15)	.94	8 (3-14)	.05
Medicaid	14 (4-53)	**.02**	5 (3-21)	.08
BMI category (kg/m^2)				
Normal (18.5-24.9)	5 (0-22)	Ref	7 (4-12)	Ref
Underweight (<18.5)	2 (1-6)	.24	13 (2-14)	.98
Overweight (25-29.9)	8 (1-21)	.80	7 (2-15)	.58
Obese (≥30)	2 (0-9)	.14	6 (3-14)	.59
Frailty assessment				
Not frail	6 (0-17)	Ref	7 (2-13)	Ref
Prefrail	4 (1-27)	.97	11 (6-15)	.96
Frail	5 (1-20)	.53	8 (3-15)	.81
ECOG performance status				
0	8 (1-26)	Ref	7 (2-11)	Ref
1	3 (0-16)	.05	8 (3-14)	.23
2	4 (0-12)	.11	7 (2-15)	.57
3	0 (0-4)	.05	9 (5-14)	.83
ADI quartile				
First quartile (least deprived)	8 (2-25)	Ref	8 (6-13)	Ref
Second quartile	8 (1-21)	.91	7 (2-11)	.60
Third quartile	2 (0-11)	.47	7 (2-13)	.92
Fourth quartile (most deprived)	4 (1-11)	.57	13 (4-23)	.08
Nodule size				
<20 mm	3 (0-25)	Ref	7 (3-13)	Ref
≥20 mm	5 (1-11)	.17	8 (2-15)	.20
Type of consultant				
Pulmonology	3 (0-11)	Ref	7 (3-15)	Ref
Thoracic surgery	6 (1-23)	**.010**	7 (2-12)	.24
Medical oncology	2 (0-31)	.14	7 (3-13)	.61
Type of biopsy performed				
Bronchoscopic	3 (0-12)	Ref	8 (3-15)	Ref
Surgical	11 (1-29)	**.03**	7 (3-11)	.42
Smoking history				
Never smoker	4 (1-21)	Ref	8 (4-15)	Ref
Former smoker	6 (1-22)	.40	7 (2-12)	.35
Current smoker	2 (0-9)	.79	8 (2-16)	.43

(Continued)

TABLE E2. Continued

Variable	Nodule ID to referral		Referral to consultation	
	Median (IQR), d	*P* value	Median (IQR), d	*P* value
Distance to hospital (miles)				
12.5-49.9 miles	5 (1-21)	Ref	6 (2-11)	Ref
<12.5 miles	2 (0-12)	.32	10 (4-15)	**.02**
≥50 miles	15 (9-33)	.28	6 (2-8)	.59
Time from start of COVID-19 pandemic to referral				
<1 y	6 (0-23)	Ref	5 (2-11)	Ref
≥1 y	3 (1-12)	.13	8 (4-15)	**.01**
Comorbidities				
CV disease	3 (1-19)	.93	7 (3-15)	.08
No CV disease	5 (0-14)	.93	7 (2-10)	.08
Lung disease	3 (1-12)	.98	7 (3-14)	.42
No lung disease	5 (0-21)	.98	7 (2-14)	.42
Diabetes mellitus	2 (1-18)	.73	7 (5-12)	.44
No diabetes mellitus	4 (0-17)	.73	7 (2-15)	.44
History of cancer	3 (0-13)	.09	7 (2-13)	.37
No history of cancer	5 (1-21)	.09	7 (3-15)	.37
Screening	2 (0-12)	.08	7 (2-14)	.81
Incidental	6 (1-20)	.08	7 (4-14)	.81
Low risk	2 (0-12)	**.02**	6 (2-11)	**.01**
High risk	6 (1-21)	**.02**	9 (4-15)	**.01**

Statistically significant comparisons are bolded. *IQR*, Interquartile range; *BMI*, body mass index; *ECOG*, Eastern Cooperative Oncology Group; *ADI*, Area Deprivation Index; *CV*, cardiovascular.

TABLE E3. Univariable analysis for time from consultation to biopsy and time from diagnosis to treatment

Variable	Consultation to biopsy		Diagnosis to treatment	
	Median (IQR), d	*P* value	Median (IQR), d	*P* value
Age				
<65 y	21 (12-28)	Ref	9 (5-34)	Ref
≥65 y	20 (13-36)	.91	32 (14-46)	**.02**
Gender				
Female	22 (12-46)	Ref	26 (7-42)	Ref
Male	19 (13-28)	.08	33 (13-49)	.18
Race				
Not Black	19 (12-28)	Ref	24 (7-42)	Ref
Black	21 (13-42)	**.03**	33 (11-46)	.14
Marital status				
Married	20 (11-27)	Ref	26 (7-45)	Ref
Divorced	24 (14-43)	.37	27 (6-53)	.95
Single/Never Married	24 (13-40)	**.009**	34 (11-43)	.91
Widowed	18 (12-52)	.17	33 (18-41)	.84
Insurance status				
Private	22 (15-28)	Ref	7 (4-23)	Ref
Medicare	20 (12-31)	.49	33 (15-46)	**<.001**
Medicaid	51 (17-75)	**.02**	34 (8-54)	**<.001**
BMI category (kg/m^2)				
Normal (18.5-24.9)	20 (14-33)	Ref	33 (18-48)	Ref
Underweight (<18.5)	14 (12-25)	.66	34 (26-43)	.54
Overweight (25-29.9)	25 (12-31)	.50	20 (6-43)	.25
Obese (≥30)	19 (10-47)	.59	27 (12-41)	.53
Frailty assessment				
Not frail	22 (13-42)	Ref	13 (6-35)	Ref
Prefrail	18 (10-29)	.34	41 (8-46)	.15
Frail	21 (15-41)	.67	37 (33-48)	**.003**
ECOG performance status				
0	24 (13-37)	Ref	8 (6-29)	Ref
1	20 (12-33)	.31	29 (11-43)	**.013**
2	21 (13-41)	.84	37 (31-48)	**.001**
3	14 (12-17)	.08	48 (42-49)	.14
ADI quartile				
First quartile (least deprived)	18 (9-28)	Ref	21 (7-29)	Ref
Second quartile	17 (9-24)	.51	25 (10-39)	.96
Third quartile	26 (16-44)	.18	29 (7-46)	.36
Fourth quartile (most deprived)	19 (13-39)	.39	37 (27-47)	.16
Nodule size				
<20 mm	21 (13-39)	Ref	29 (8-46)	Ref
≥20 mm	20 (10-33)	.69	28 (12-42)	.25
Type of consultant				
Pulmonology	18 (10-30)	Ref	34 (23-46)	Ref
Thoracic surgery	25 (15-42)	.17	9 (6-35)	**.002**
Medical oncology	22 (22-26)	.91	45 (28-62)	.13
Type of biopsy performed				
Bronchoscopic	17 (10-26)	Ref	36 (25-48)	Ref
Surgical	28 (20-53)	**.001**	6 (4-8)	**<.001**
Smoking history				
Never smoker	20 (13-25)	Ref	22 (7-33)	Ref
Former smoker	18 (10-34)	.80	27 (10-43)	.13
Current smoker	25 (17-42)	.08	35 (8-48)	.14

(Continued)

TABLE E3. Continued

Variable	Consultation to biopsy		Diagnosis to treatment	
	Median (IQR), d	*P* value	Median (IQR), d	*P* value
Distance to hospital (miles)				
12.5-49.9 miles	20 (13-31)	Ref	26 (8-44)	Ref
<12.5 miles	21 (13-41)	.49	32 (11-46)	.39
≥50 miles	19 (13-24)	.29	10 (6-27)	.15
Time from start of COVID-19 pandemic to referral				
<1 y	21 (12-30)	Ref	14 (6-30)	Ref
≥1 y	20 (12-41)	.43	35 (25-48)	**<.001**
Comorbidities				
CV disease	20 (12-40)	.34	34 (12-48)	**.019**
No CV disease	21 (12-30)	.34	21 (6-36)	**.019**
Lung disease	19 (13-36)	.64	34 (20-46)	.12
No lung disease	21 (11-34)	.64	22 (7-42)	.12
Diabetes mellitus	17 (8-27)	.19	29 (25-49)	.25
No diabetes mellitus	21 (13-36)	.19	27 (7-42)	.25
History of cancer	18 (13-27)	.10	28 (12-40)	.32
No history of cancer	22 (12-40)	.10	29 (7-46)	.32
Initial treatment				
Surgery	22 (13-42)	Ref	9 (5-28)	Ref
Neoadjuvant therapy*	9 (7-11)	.15	25 (23-29)	.88
SBRT	21 (14-36)	**.004**	41 (31-50)	**<.001**
Screening	25 (14-41)	.46	26 (7-40)	.21
Incidental	19 (10-30)	.46	32 (16-46)	.21
Low risk	21 (13-34)	.87	33 (20-48)	.12
High risk	20 (12-34)	.87	25 (7-43)	.12

Statistically significant comparisons are bolded. *IQR*, Interquartile range; *BMI*, body mass index; *ECOG*, Eastern Cooperative Oncology Group; *ADI*, Area Deprivation Index; *CV*, cardiovascular; *SBRT*, stereotactic body radiotherapy. *Neoadjuvant therapy includes chemotherapy with immunotherapy or radiotherapy.

TABLE E4. Univariable Cox analysis for time to diagnosis and time to treatment

Variable	TTD		TTT	
	Median (IQR), d	*P* value	Median (IQR), d	*P* value
Age				
<65 y	34 (26-56)	Ref	49 (31-74)	Ref
≥65 y	34 (22-56)	.75	68 (48-84)	.12
Gender				
Female	41 (26-64)	Ref	68 (45-91)	Ref
Male	29 (21-37)	.05	61 (40-77)	.50
Race				
Not Black	30 (19-44)	Ref	49 (36-77)	Ref
Black	41 (26-69)	**<.001**	72 (54-96)	**<.001**
Marital status				
Married	32 (22-47)	Ref	54 (38-76)	Ref
Divorced	30 (25-56)	.90	64 (46-85)	.78
Single/Never married	37 (28-71)	**.02**	68 (53-102)	**.01**
Widowed	44 (20-73)	**.03**	79 (47-96)	**.02**
Insurance status				
Private	30 (26-48)	Ref	37 (27-54)	Ref
Medicare	34 (22-55)	.18	68 (48-88)	**<.001**
Medicaid	56 (21-77)	.09	80 (67-122)	**<.001**
BMI category (kg/m^2)				
Normal (18.5-24.9)	32 (26-59)	Ref	67 (49-96)	Ref
Underweight (<18.5)	31 (25-50)	.57	67 (49-76)	.21
Overweight (25-29.9)	36 (24-54)	.18	58 (40-78)	**.03**
Obese (≥30)	34 (18-64)	.49	65 (46-85)	.21
Frailty assessment				
Not frail	34 (26-56)	Ref	52 (38-82)	Ref
Prefrail	38 (27-62)	.81	67 (54-80)	.94
Frail	39 (28-65)	.52	80 (64-97)	.05
ECOG performance status				
0	34 (27-52)	Ref	48 (28-75)	Ref
1	35 (25-58)	.86	68 (47-84)	.08
2	34 (20-61)	.51	76 (53-108)	**.02**
3	28 (21-34)	.23	64 (64-76)	.66
ADI quartile				
First quartile (least deprived)	33 (23-53)	Ref	46 (35-84)	Ref
Second quartile	29 (19-37)	.48	49 (34-66)	.67
Third quartile	39 (21-60)	.27	68 (49-84)	.11
Fourth quartile (most deprived)	41 (27-68)	.07	77 (67-108)	**<.01**
Nodule size				
<20 mm	36 (26-55)	Ref	66 (43-82)	Ref
≥20 mm	32 (19-56)	.68	62 (45-88)	.45
Type of consultant				
Pulmonology	31 (21-56)	Ref	69 (55-95)	Ref
Thoracic surgery	37 (28-56)	.77	48 (33-75)	.47
Medical oncology	33 (16-53)	.59	72 (48-82)	.36
Type of biopsy performed				
Bronchoscopic	28 (18-47)	Ref	73 (52-88)	Ref
Surgical	46 (33-61.8)	**.02**	43 (29-66)	**<.001**
Smoking history				
Never smoker	34 (27-45)	Ref	54 (31-88)	Ref
Former smoker	31 (19-55)	.86	56 (41-78)	.86
Current smoker	41 (27-64)	.15	74 (54-96)	.07

(Continued)

TABLE E4. Continued

Variable	TTD		TTT	
	Median (IQR), d	***P* value**	**Median (IQR), d**	***P* value**
Distance to hospital (miles)				
12.5-49.9 miles	33 (22-48)	Ref	56 (40-81)	Ref
<12.5 miles	40 (24-66)	.135	72 (52-94)	.05
≥50 miles	30 (23-39)	.33	45 (28-54)	.08
Time from start of COVID-19 pandemic to referral				
<1 y	32 (19-48)	Ref	49 (35-68)	Ref
≥1 y	37 (26-64)	**.02**	76 (55-91)	**<.001**
Comorbidities				
CV disease	34 (21-57)	.45	68 (47-88)	.05
No CV disease	34 (25-53)	.45	55 (34-79)	.05
Lung disease	35 (21-56)	.79	69 (51-88)	.18
No lung disease	34 (25-55)	.79	57 (38-82)	.18
Diabetes mellitus	27 (17-48)	.22	68 (44-82)	.91
No diabetes mellitus	35 (26-56)	.22	64 (45-84)	.91
History of cancer	31 (22-42)	.06	64 (39-82)	.23
No history of cancer	38 (24-63)	.06	65 (47-92)	.23
Initial treatment				
Surgery	36 (26-60)	Ref	51 (38-80)	Ref
Neoadjuvant therapy*	16 (15-21)	**.006**	40 (38-49)	.18
SBRT	37 (26-55)	.92	76 (63-90)	.89
Screening	38 (27-57)	.41	61 (41-81)	.86
Incidental	31 (21-53)	.41	68 (45-87)	.86
Low risk	35 (21-49)	.40	64 (49-78)	.51
High risk	34 (23-60)	.40	65 (40-88)	.51

Statistically significant comparisons are bolded. *TTD*, Time to diagnosis; *TTT*, time to treatment; *IQR*, interquartile range; *BMI*, body mass index; *ECOG*, Eastern Cooperative Oncology Group; *ADI*, Area Deprivation Index; *CV*, cardiovascular; *SBRT*, stereotactic body radiotherapy. *Neoadjuvant therapy includes chemotherapy with immunotherapy or radiotherapy.

TABLE E5. Factors associated with time to diagnosis and treatment in multivariable Cox regression analysis, excluding surgical biopsies

Variable	TTD		TTT	
	HR (95% CI)	*P* value	HR (95% CI)	*P* value
Age				
<65 y	Ref	Ref	Ref	Ref
≥65 y	1.58 (0.31-8.08)	.58	3.05 (0.61-15.31)	.18
Gender – female vs male	0.48 (0.19-1.20)	.12	0.28 (0.08-1.04)	.06
Not Black vs Black race	2.31 (0.63-8.49)	.21	0.49 (0.05-4.63)	.53
Marital status				
Married	Ref	Ref	Ref	Ref
Divorced	1.18 (0.27-5.15)	.82	0.07 (0.01-0.75)	**.03**
Single/never married	0.62 (0.23-1.66)	.34	1.83 (0.35-9.59)	.48
Widowed	0.22 (0.07-0.72)	**.012**	0.15 (0.03-0.87)	**.04**
Insurance status				
Private	Ref	Ref	Ref	Ref
Medicare	1.00 (0.11-8.69)	.99	0.73 (0.05-11.02)	.82
Medicaid	0.89 (0.04-21.40)	.94	0.01 (0.00-0.65)	**.03**
Frailty assessment				
Not frail	Ref	Ref	Ref	Ref
Prefrail	1.63 (0.54-4.92)	.39	0.55 (0.13-2.33)	.42
Frail	1.73 (0.68-4.45)	.25	0.38 (0.08-1.84)	.23
ADI quartile				
First quartile (least deprived)	Ref	Ref	Ref	Ref
Second quartile	1.83 (0.51-6.61)	.36	0.42 (0.03-5.82)	.52
Third quartile	1.68 (0.50-5.68)	.40	0.27 (0.02-3.33)	.31
Fourth quartile (most deprived)	2.58 (0.51-12.97)	.25	0.08 (0.01-1.00)	.05
Distance to hospital (miles)				
12.5-49.9 miles	Ref	Ref	Ref	Ref
<12.5 miles	0.61 (0.18-2.07)	.43	0.14 (0.02-0.76)	.02
≥50 miles	3.44 (0.57-20.57)	.18	1.55 (0.15-16.19)	.72
Time from start of COVID-19 pandemic to referral				
<1 y	Ref	Ref	Ref	Ref
≥1 y	0.37 (0.14-0.96)	**.04**	1.24 (0.32-4.81)	.75
History of cardiovascular disease	2.15 (0.68-6.84)	.19	1.61 (0.36-7.24)	.53
Initial treatment				
Surgery	–	–	Ref	Ref
Neoadjuvant therapy*	–	–	13.82 (1.14-167.58)	**.04**
SBRT	–	–	0.03 (0.00-0.19)	**<.001**

Statistically significant comparisons are bolded. *TTD*, Time to diagnosis; *TTT*, time to treatment; *HR*, hazard ratio; *ADI*, Area Deprivation Index; *SBRT*, stereotactic body radiotherapy. *Neoadjuvant therapy includes chemotherapy with immunotherapy or radiotherapy.