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Original Article

Factors associated with time to prostate cancer treatment initiation during the COVID-19 pandemic

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Abstract: Time from cancer diagnosis to treatment initiation (TTI) can influence clinical outcomes and is a measure of care quality. This study aimed to evaluate the associations between clinical, sociodemographic, and facility-level factors with treatment delays among patients with prostate cancer during the COVID-19 pandemic. We conducted a retrospective analysis of the National Cancer Database (NCDB) for prostate cancer cases diagnosed in 2020 and 2021. We assessed the associations between clinical factors, sociodemographic variables (age, race, ethnicity, sex, income, education, insurance), facility-related factors (facility type, geographic region), and TTI. Multivariable logistic regression was used to identify factors associated with prolonged TTI, defined as the top decile of days to treatment. We identified 160,863 patients, with a median TTI of 71 days (IQR: 43-107). The 90th percentile for TTI was 154 days. Compared to White race, Black (OR 1.39, 95% CI 1.33-1.45), Asian (OR 1.28, 95% CI 1.08-1.52), and Hispanic (OR 1.31, 95% CI 1.21-1.41) patients had significantly longer TTI. Treatment at academic (OR 1.84, 95% CI 1.70-2.00), network (OR 1.37, 95% CI 1.25-1.49), and comprehensive facilities (OR 1.16, 95% CI 1.07-1.26) was associated with longer TTI compared to community facilities. Lastly, private insurance was associated with shorter delays compared to uninsured individuals (OR 0.75, 95% CI 0.71-0.81). Sociodemographic disparities, including race, insurance status, and treatment facility, were associated with longer TTI among prostate cancer patients during the COVID-19 pandemic. These findings can guide efforts to improve timeliness of cancer care.

Keywords: Prostate cancer, time-to-treatment, healthcare disparities, COVID-19

Introduction

The COVID-19 pandemic significantly disrupted healthcare systems worldwide, leading to widespread delays in non-COVID-related medical care, including for patients affected by cancer [1-3]. Among patients with cancer, prostate cancer care was commonly delayed due to lower acuity in treating localized disease, including some experiencing substantial delays in treatment [4-7]. These delays, particularly for outliers experiencing more pronounced delays in time to treatment initiation (TTI), raise concerns about potential adverse effects on disease outcomes [8-10]. The impact of the pandemic on the delivery of prostate cancer care remains an important area of investigation, given evidence of long-lasting disruptions in cancer screening.

Few studies have explored delays in prostate cancer treatment during the COVID-19 pandemic [11-14]. Bernstein et al. reported a substantial reduction in prostate cancer procedures, with biopsy volumes decreasing by 55% and prostatectomy volumes dropping by 39% during the pandemic. Similarly, Lee et al. observed significant declines in outpatient visits and surgeries, while Shin et al. documented a notable decrease in PSA testing during the same period. Despite the well-documented impact of COVID on delaying prostate cancer diagnostic and treatment procedures, the specific patient-related factors contributing to extreme delays have been explored.

Prior to the pandemic, multiple studies had already identified disparities in prostate cancer diagnosis and treatment that were influenced

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by a combination of patient- and facility-level characteristics. Clinical features such as lower prostate-specific antigen (PSA) levels, low Gleason scores, and early-stage disease have been associated with longer TTIs, likely reflecting de-prioritization of perceived low-risk cases [15-17]. Sociodemographic characteristics also contribute significantly to treatment delays. Black race, lower income, uninsured status, and lower educational attainment have been repeatedly associated with decreased access to timely cancer care, including prostate cancer treatment [18-21]. Furthermore, treatment facility-related factors - including facility type (academic vs. community), location (urban vs. rural), volume, and resource availability - can influence the timeliness of diagnosis and treatment. For example, patients treated at high-volume academic centers may receive more guideline-concordant care but may also face longer wait times due to higher patient loads [22, 23]. In contrast, patients at low-resource community hospitals may experience delays due to staffing shortages or limited surgical availability [24]. During the COVID-19 pandemic, these preexisting disparities may have been amplified by pandemic-related service disruptions and triage policies.

This study aims to focus on three key categories of factors that may have influenced treatment delays for prostate cancer patients: clinical, sociodemographic, as well as those related to treatment facilities. The goal of this report is to better understand factors most vulnerable to disruptions in prostate cancer care. Additionally, this study seeks to determine whether patients who experienced prolonged delays in receiving prostatectomy had increased likelihood of Gleason upgrading at the time of surgery, which could indicate tumor progression during the delay period and highlight the potential clinical consequences of treatment disruptions. A better understanding of how patient characteristics and healthcare system dynamics contribute to treatment delays - and the effects of those delays - can offer valuable insights for improving healthcare delivery, especially during times of crisis. This knowledge can help ensure that vulnerable patient populations receive timely and appropriate care.

Materials and methods

Study cohort

This study utilized data from the National Cancer Database (NCDB) to identify patients diagnosed with prostate cancer between January 1, 2020, and December 31, 2021. Inclusion criteria were male patients aged 18 years or older with histologically confirmed prostate adenocarcinoma, documented dates of diagnosis and treatment initiation (including surgery, radiation, or systemic therapy), and available key sociodemographic data such as age, race/ethnicity, insurance status, and ZIP code-level median income and educational attainment. Clinical data required included prostate-specific antigen (PSA) levels, Gleason score, and NCCN risk category [25]. Treatment facility characteristics, including facility type and location, were also required.

Patients were excluded if they had missing or incomplete data for any of the above critical variables, including time to treatment initiation (TTI), treatment type, or facility information. Cases with TTI exceeding 365 days were excluded to omit patients likely managed with active surveillance or watchful waiting rather than definitive treatment.

Clinical, sociodemographic, and facility-related factors

Clinical characteristics evaluated included patient age (reported as mean ± standard deviation), prostate cancer risk group categorized according to National Comprehensive Cancer Network (NCCN) guidelines into low, intermediate, and high risk, and the Charlson-Deyo Comorbidity Index score (0, 1, 2, or ≥3) as a measure of patient comorbidity burden. Treatment types were classified into hormonal therapy, surgery of the primary tumor site, chemotherapy, and radiation therapy. Additionally, we assessed whether patients received care at more than one Commission on Cancer (CoC)-accredited facility during their treatment course to capture potential fragmentation of care. Sociodemographic variables encompassed self-reported race and ethnicity, including White, Black, Asian, South Asian, and Hispanic or Spanish Origin, insurance status (uninsured, private insurance, Medicaid, Medicare, or other

government insurance), and socioeconomic indicators based on patients' ZIP code of residence, such as median household income categorized into four brackets (<$30,000; $30,000-$34,999; $35,000-$45,999; and ≥$46,000) and educational attainment defined by the percentage of adults without a high school diploma in the ZIP code (>29%, 20%-28.9%, 14%-19.9%, and <14%). Facility-related factors included facility type, classified as community cancer programs, comprehensive community cancer programs, academic/research programs, or integrated network cancer programs per CoC definitions, as well as urbanicity categorized into rural, urban, or metropolitan areas based on Rural-Urban Commuting Area (RUCA) codes, to assess the impact of treatment center characteristics and geographic location on time to treatment initiation.

Study outcomes

The primary outcome was a prolonged delay in treatment, defined as having a time to treatment initiation (TTI) at or above the 90th percentile of the TTI distribution for the entire patient cohort. This threshold corresponds to the top 10% of patients with the longest treatment delays. We selected this cutoff to focus on extreme delays while preserving adequate sample size for meaningful statistical analysis. Using the 90th percentile better accounts for the right-skewed distribution of TTI compared to standard deviation-based thresholds and helps identify clinically significant delays in prostate cancer treatment.

Among those who underwent radical prostatectomy, we examined Gleason upgrading as a secondary outcome, defined as an increase in the Gleason score from biopsy to radical prostatectomy. The Gleason score is a histopathological grading system used to evaluate the aggressiveness of prostate adenocarcinoma based on the architectural patterns of tumor cells observed in tissue specimens. It ranges from 6 to 10 and is calculated by summing the two most prevalent Gleason patterns observed in the tumor. In this study, both clinical (biopsy) and pathologic (post-prostatectomy) Gleason scores were obtained from the NCDB, which records values reported by pathologists at participating institutions. Gleason upgrading was used as a proxy for potential tumor progression during treatment delay.

Several factors were examined for their potential association with being in the top decile of TTI, including sociodemographic characteristics (age, race/ethnicity, insurance status, median income, and educational attainment at the ZIP code level), clinical characteristics (risk group, Charlson-Deyo Comorbidity Index score, and type of treatment received), and facility-related factors (facility type, urbanicity, and treatment at multiple cancer centers).

Statistical analysis

Descriptive statistics were initially used to summarize the distribution of TTI, including the mean, median, standard deviation, and percentiles, with a particular focus on the 90th percentile as the cutoff for extreme delays.

Univariable analysis compared patients below and above the 90th percentile, assessing sociodemographic, clinical, and facility-related factors using chi-square tests for categorical variables and t-tests for continuous variables (**Table 1**).

A multivariable logistic regression identified factors independently associated with extreme delays, including variables significant in univariable analysis. Odds ratios (OR) and 95% confidence intervals (CI) were reported.

Given differences in treatment urgency, a sensitivity analysis examined high-risk prostate cancer patients separately. Additionally, among those treated with prostatectomy, a logistic regression assessed the association between TTI and Gleason upgrading.

All analyses were performed using R Version 2023.12.0+369, with statistical significance set at $P<0.05$.

Results

Study cohort

A total of 160,863 patients with prostate cancer were included in the analysis. Of these, 144,506 patients (90%) experienced treatment initiation times (TTI) of less than 154 days, while 16,357 patients (10%) had TTI of 154 days or more. The median TTI for the overall cohort was 71 days (interquartile range [IQR]: 43.0-107.0).

Time to treatment initiation (TTI) was longer for Black patients compared to White patients,

Table 1. Univariable comparison of clinical, sociodemographic, and treatment facility characteristics between prostate cancer patients with treatment initiation times (TTI) above and below the 90th percentile (154 days)

Patient and facility factors	Study Cohort (N=160, 863)	TTI <154 days (N=144, 506)	TTI >=154 days (N=16, 357)	*P*-Value
Age (mean ± SD)	66.7±8.1	66.9±8.2	64.9±7.5	<0.001
Race				
White	132,460 (82.4%)	119,945 (83.0%)	12,515 (76.5%)	
Asian	1,515 (0.9%)	1,354 (0.9%)	161 (1.0%)	
Black	26,142 (16.2%)	22,530 (15.6%)	3,612 (22.1%)	
South Asian	746 (0.5%)	677 (0.5%)	69 (0.4%)	
Hispanic Spanish Origin	7,505 (4.7%)	6,569 (4.5%)	936 (5.7%)	<0.001
Facility type				<0.001
Community	10,281 (6.4%)	9,534 (6.6%)	747 (4.6%)	
Comprehensive	59,948 (37.3%)	54,861 (37.9%)	5,087 (31.1%)	
Academic	59,968 (37.3%)	52,445 (36.3%)	7,523 (46.0%)	
Network	30,666 (19.1%)	27,666 (19.1%)	3,000 (18.3%)	
Urbanicity				<0.001
Rural	8,420 (5.2%)	7,558 (5.2%)	862 (5.3%)	
Urban	24,762 (15.4%)	22,534 (15.6%)	2,228 (13.6%)	
Metropolitan	137,681 (85.7%)	114,414 (79.1%)	13,267 (81.1%)	
Risk				<0.001
Low	17,145 (10.7%)	14,067 (9.7%)	3,078 (18.8%)	
Intermediate	90,263 (56.1%)	79,221 (54.8%)	11,042 (67.5%)	
High	53,455 (33.3%)	51,218 (35.4%)	2,237 (13.7%)	
Charlson Deyon Score				<0.001
0	125,001 (77.8%)	112,909 (78.1%)	13,092 (80.0%)	
1	22,263 (13.8%)	20,152 (13.9%)	2,111 (12.9%)	
2	7,173 (4.5%)	6,528 (4.5%)	645 (3.9%)	
≥3	5,426 (3.4%)	4,917 (3.4%)	509 (3.1%)	
Treatment Type				<0.001
Hormonal Therapy	59,779 (37.2%)	57,160 (39.5%)	2,619 (16.0%)	
Surgery of Primary Site	85,817 (53.4%)	77,103 (53.3%)	8,714 (53.2%)	
Chemotherapy	2,265 (1.4%)	2,240 (1.5%)	25 (0.2%)	
Radiation Therapy	70,302 (43.7%)	61,464 (42.5%)	8,838 (54.0%)	
Treatment at >1 Coc Facility				<0.001
No	143,723 (89.4%)	129,270 (89.4%)	14,453 (88.3%)	
Yes	16,140 (10.0%)	15,236 (10.5%)	1,904 (11.6%)	
Insurance Status (%)				<0.001
Not Insured	1,568 (1.0%)	1,382 (0.9%)	186 (1.1%)	
Private Insurance	58,547 (36.4%)	53,111 (36.7%)	5,436 (33.2%)	
Medicaid	5,944 (3.7%)	5,093 (3.5%)	851 (5.2%)	
Medicare	87,959 (54.7%)	79,385 (54.9%)	8,574 (52.4%)	
Other Government	5,528 (3.4%)	4,373 (3.0%)	1,155 (7.0%)	
Median Income (%)				<0.001
<30000 $	13,992 (8.7%)	12,434 (8.6%)	1,558 (9.5%)	
30000 $-34999 $	20,421 (12.7%)	18,436 (12.7%)	1,985 (12.1%)	
35000 $-45999 $	35,217 (21.9%)	31,646 (21.8%)	3,571 (21.8%)	
≥46000 $	59,654 (37.1%)	53,542 (37.0%)	6,112 (37.3%)	

No High School Education at ZIP code (%)				<0.001
>29%	17,090 (10.6%)	15,170 (10.5%)	1,920 (11.7%)	
20%-28.9%	26,867 (16.7%)	24,033 (16.6%)	2,834 (17.3%)	
14%-19.9%	31,096 (19.3%)	28,015 (19.4%)	3,081 (18.8%)	
<14%	54,202 (33.7%)	48,817 (33.8%)	5,385 (32.9%)	

Table 2. Multivariable logistic regression analysis of factors associated with treatment initiation times (TTI) above the 90th percentile (154 days), with odds ratios (ORs) and 95% confidence intervals (CIs) reported

Patient and facility factors	OR (95% CI)	*P*-Value
Age	0.97 (0.97-0.97)	<0.001
Race		
White	REF	
Asian	1.28 (1.08-1.52)	0.004
Black	1.39 (1.33-1.45)	<0.001
South Asian	0.96 (0.74-1.24)	0.749
Hispanic Spanish Origin	1.31 (1.21-1.41)	<0.001
Facility type		
Community	REF	
Comprehensive	1.16 (1.07-1.26)	<0.001
Academic	1.84 (1.70-2.00)	<0.001
Network	1.37 (1.25-1.49)	<0.001
Urbanicity		
Rural	REF	
Urban	1.01 (0.93-1.09)	0.877
Metropolitan	0.97 (0.89-1.06)	0.493
Risk		
Low	REF	
Intermediate	0.72 (0.69-0.75)	<0.001
High	0.35 (0.33-0.37)	<0.001
Charlson Deyon Score		
0	REF	
1	0.95 (0.90-1.00)	0.051
2	0.96 (0.88-1.04)	0.297
≥3	0.96 (0.91-1.11)	0.961
Treatment Type		
Hormonal Therapy	REF	
Surgery of Primary Site	2.47 (2.35-2.58)	<0.001
Chemotherapy	0.24 (0.16-0.37)	<0.001
Radiation Therapy	3.14 (3.00-3.28)	<0.001
Treatment at >1 Coc Facility		
No	REF	
Yes	1.22 (1.15-1.28)	<0.001
Insurance Status (%)		
Not Insured	REF	
Private Insurance	0.75 (0.71-0.81)	<0.001
Medicaid	1.16 (0.97-1.38)	0.098
Medicare	0.88 (0.75-1.04)	0.123
Other Government	1.27 (1.10-1.44)	<0.001

with a median of 83 days (IQR: 58.0-116.0) versus 69 days (IQR: 45.0-98.0), respectively. Similarly, Hispanic patients faced longer delays than non-Hispanic patients (median: 81 vs. 71 days, IQR: 57.0-113.0 vs. 47.0-98.0).

Factors associated with being in the top decile of TTI

The multivariable regression analysis identified several factors independently associated with (TTI ≥154 days) (**Table 2**). Older age was inversely associated with delays (OR 0.97, 95% CI: 0.97-0.97, P<0.001). Race was associated with TTI, including higher odds of delayed treatment among Black (OR 1.39, 95% CI: 1.33-1.45, P<0.001) and Hispanic patients (OR 1.31, 95% CI: 1.21-1.41, P<0.001) compared to non-Hispanic white patients. Facility type was also associated with time to treatment, with patients treated at academic centers (OR 1.84, 95% CI: 1.70-2.00, P<0.001) and network centers (OR 1.37, 95% CI: 1.25-1.49, P<0.001) having higher odds of delays compared to those treated at community centers. Risk group was strongly associated with delays, with intermediate- (OR 0.72, 95% CI: 0.69-0.75, P< 0.001) and high-risk patients (OR 0.35, 95% CI: 0.33-0.37, P<0.001) less likely to experience delays compared to the low-risk group. Comorbidity, as measured by the Charlson-

Median Income (%)		
<30000 $	REF	
30000 $-34999 $	0.97 (0.90-1.05)	0.479
35000 $-45999 $	1.05 (0.97-1.13)	0.257
≥46000 $	1.03 (0.94-1.11)	0.551
No High School Education at ZIP code (%)		
>29%	REF	
20%-28.9%	0.98 (0.91-1.05)	0.519
14%-19.9%	0.95 (0.88-1.03)	0.199
<14%	0.94 (0.87-1.02)	0.137

Table 3. Multivariable logistic regression analysis of factors associated with treatment initiation times (TTI) above the 90th percentile (117 days) for the high-risk patient subpopulation, with odds ratios (ORs) and 95% confidence intervals (CIs) reported

Patient and facility factors	OR (95% CI)	*P*-Value
Age	0.98 (0.98-0.98)	<0.001
Race		
White	REF	
Asian	1.27 (0.97-1.67)	0.076
Black	1.71 (1.59-1.85)	<0.001
South Asian	0.76 (0.46-1.27)	0.306
Hispanic Spanish Origin	1.27 (1.12-1.44)	<0.001
Facility type		
Community	REF	
Comprehensive	1.31 (1.13-1.52)	<0.001
Academic	1.92 (1.66-2.23)	<0.001
Network	1.50 (1.28-1.75)	<0.001
Urbanicity		
Rural	REF	
Urban	1.15 (0.98-1.31)	0.068
Metropolitan	1.05 (0.98-1.34)	0.073
Charlson Deyon Score		
0	REF	
1	1.05 (0.96-1.14)	0.224
2	0.99 (0.87-1.14)	0.980
≥3	1.15 (0.99-1.13)	0.050
Treatment Type		
Hormonal Therapy	REF	
Surgery of Primary Site	2.25 (2.12-2.39)	<0.001
Chemotherapy	0.36 (0.26-0.48)	<0.001
Radiotherapy	3.09 (2.95-3.26)	<0.001
Treatment at >1 Coc Facility		
No	REF	
Yes	1.08 (0.98-1.18)	0.073
Insurance Status (%)		
Not Insured	REF	
Private Insurance	0.75 (0.65-0.85)	<0.001

Deyo score, was not associated with treatment delay.

Treatment was also associated with TTI. Surgery of the primary site (OR 2.47, 95% CI: 2.35-2.58, P<0.001) and radiation therapy (OR 3.14, 95% CI: 3.00-3.28, P<0.001) were associated with higher odds of delays, while chemotherapy (OR 0.24, 95% CI: 0.16-0.37, P<0.001) was associated with lower odds of delays compared to hormonal therapy. Patients treated at multiple cancer centers had higher odds of delays (OR 1.22, 95% CI: 1.15-1.28, P<0.001). Patients with private insurance had lower odds of treatment delay (OR 0.75, 95% CI: 0.71-0.81, P<0.001) compared to the uninsured. Income and education at the ZIP code level did not show significant associations with delays (P> 0.05).

When focusing on the high-risk patient population (**Table 3**), similar trends in treatment delays were observed.

Association between TTI and Gleason Upgrading

A total of 76,036 patients underwent radical prostatectomy, of whom 11,078 (14.5%) demonstrated Gleason score upgrading from biopsy to final pathology. Clinically, the most common biopsy Gleason score was 7 (63.9%), followed by scores of 8 (14.6%), 6 (11.3%), 9 (9.6%), and 10 (0.6%). In contrast, pathologic Gleason scores were most frequently 7 (76.3%), with lower proportions of scores 9 (12.4%), 8 (5.9%), 6 (5.2%), and 10 (0.2%).

Table 4 presents the multivariable logistic regression analysis examining the impact of

Medicaid	1.00 (0.75-1.32)	0.975
Medicare	0.86 (0.67-1.11)	0.268
Other Government	1.28 (0.96-1.71)	0.090
Median Income (%)		
<30000 $	REF	
30000 $-34999 $	0.91 (0.81-1.04)	0.190
35000 $-45999 $	0.96 (0.84-1.09)	0.545
≥46000 $	0.99 (0.86-1.13)	0.903
No High School Education at ZIP code (%)		
>29%	REF	
20%-28.9%	0.88 (0.79-0.99)	0.045
14%-19.9%	0.84 (0.74-0.95)	0.008
<14%	0.74 (0.65-0.85)	<0.001

Table 4. Multivariable logistic regression analysis of factors associated with Gleason upgrading among patients with prostate cancer patients who underwent radical prostatectomy, with odds ratios (ORs) and 95% confidence intervals (CIs) reported

Patient and facility factors	OR (95% CI)	*P*-Value
Top decile of TTI (≥154 days)		
No	REF	
Yes	1.66 (1.57-1.76)	<0.001
Age	0.98 (0.98-0.99)	<0.001
Race		
White	REF	
Asian	0.86 (0.69-1.08)	0.209
Black	1.10 (1.05-1.15)	<0.001
South Asian	0.90 (0.66-1.23)	0.530
Hispanic Spanish Origin	1.16 (1.06-1.27)	<0.001
Facility type		
Community	REF	
Comprehensive	1.04 (0.94-1.16)	0.391
Academic	0.90 (0.81-1.00)	0.069
Network	0.92 (0.82-1.02)	0.135
Urbanicity		
Rural	REF	
Urban	1.05 (0.95-1.16)	0.321
Metropolitan	0.99 (0.91-1.09)	0.956
Charlson Deyon Score		
0	REF	
1	0.97 (0.91-1.03)	0.392
2	0.93 (0.84-1.04)	0.266
≥3	1.08 (0.95-1.24)	0.217
Treatment at >1 Coc Facility		
No	REF	
Yes	1.02 (0.96-1.09)	0.410
Insurance Status (%)		
Not Insured	REF	
Private Insurance	1.02 (0.83-1.24)	0.850

treatment delays on Gleason upgrading, while adjusting for potential confounding variables. Higher TTI (≥154 days) was significantly associated with Gleason upgrading (OR 1.66, 95% CI: 1.57-1.76, P<0.001). Race and ethnicity were also associated with odds of upgrading: Black race (OR 1.10, 95% CI: 1.05-1.15, P<0.001) was associated with higher odds of upgrading compared to non-Hispanic White, and Hispanic/Latino ethnicity (OR 1.16, 95% CI: 1.06-1.27, P< 0.001) was similarly associated with higher odds of upgrading compared to non-Hispanic patients. Area-level socioeconomic factors were also associated with Gleason score upgrading. Specifically, residing in areas with higher educational attainment (defined as <14% of the population without a high school education) was associated with lower odds of upgrading (OR 0.86; 95% CI: 0.78-0.95; P=0.005).

Discussion

This study examined factors associated with long delays in prostate cancer treatment in the years coinciding with the COVID-19 pandemic. Our findings highlight significant sociodemographic, clinical, and facility-related factors that were associated with time to treatment, emphasizing the need for targeted interventions to ensure timely care in future public health crises.

Younger patients were more likely to experience long delays, consistent with trends in other cancers during the pandemic. This may reflect patient preferences or healthcare system prioritization of older, higher-risk individuals [21, 22]. Ra-

Medicaid	0.89 (0.71-1.12)	0.358
Medicare	1.03 (0.84-1.27)	0.732
Other Government	0.99 (0.77-1.25)	0.936
Median Income (%)		
<30000 $	REF	
30000 $-34999 $	1.01 (0.92-1.12)	0.755
35000 $-45999 $	0.98 (0.89-1.08)	0.764
≥46000 $	1.06 (0.95-1.17)	0.277
No High School Education at ZIP code (%)		
>29%	REF	
20%-28.9%	0.94 (0.86-1.03)	0.240
14%-19.9%	0.93 (0.85-1.02)	0.165
<14%	0.86 (0.78-0.95)	0.005

cial disparities were also evident, with Black and Hispanic patients experiencing longer TTI than White patients, aligning with existing literature on systemic barriers to timely care [15, 16].

Facility type played a significant role, with patients at academic centers facing longer delays than those at community centers, likely due to resource strain and higher COVID-19 caseloads [23]. These findings underscore the need for flexible resource allocation models during crises.

Patients in intermediate and high-risk categories were less likely to experience delays, suggesting prioritization of urgent cases. However, delays among low-risk patients raise concerns about the long-term impact of postponed care.

Treatment type influenced delays, with patients receiving hormonal therapy, surgery, or chemotherapy less likely to experience delays due to perceived urgency. Conversely, those receiving less urgent care or treated at multiple centers faced longer delays, reflecting logistical challenges of fragmented care systems.

Insurance status was another key factor, with privately insured patients experiencing shorter delays than those with Medicaid or other government insurance, consistent with previous studies on sociodemographic influences on cancer care delays [15, 16]. Additionally, patients with other government insurance had higher odds of delays, highlighting systemic differences in care prioritization. Addressing these disparities requires policy changes to ensure equitable access to timely treatment.

Although ZIP code-level income and education were not significantly associated with delays, patients in areas with higher educational disadvantage were more likely to experience delays, suggesting broader social determinants of health played a role [24]. Further research is needed to explore how these factors interact with healthcare delivery and access.

Longer treatment delays were associated with higher odds of Gleason upgrading from biopsy to surgery, though it remains unclear whether delays directly contributed or whether lower utilization of tools such as MRI and targeted biopsy played a role. Nonetheless, this underscores the importance of timely prostate cancer management, as delays may influence disease progression and clinical decision-making.

Treatment delays observed during the COVID-19 pandemic highlight both systemic challenges intensified by the crisis and long-standing healthcare inequities. The longer delays among younger patients could reflect self-selection or explicit attempts to prioritize higher-risk individuals. The racial disparities in delays suggest that the pandemic may have exacerbated pre-existing barriers, including differential access to care and insurance coverage gaps, underscoring the urgent need for sustained policy reforms aimed at equity. Facility-related differences, with academic centers facing longer delays, point to resource strain and the dual role of these centers as referral and COVID treatment hubs, indicating that future preparedness should include redistributing patient loads or expanding capacity at high-demand centers. Although prioritization of intermediate and high-risk patients aligns with clinical urgency, delays in low-risk patients raise concerns about potential negative outcomes and highlight the importance of clear communication and follow-up strategies. Insurance status as a predictor of delay further reflects broader social determinants of health, suggesting that expanding coverage and reducing administrative barriers are critical to ensuring timely care. Finally, the association between delays and

Gleason upgrading, while likely not indicating a causal relationship, emphasize the role for adjunctive diagnostic tools to more accurately characterize cancer risk.

This study has limitations. The retrospective design relies on National Cancer Database data, which lacks certain variables, such as patient preferences and provider decision-making. Additionally, while we examined treatment delays and Gleason upgrading, we did not assess long-term survival outcomes. The lack of a well-defined threshold for clinically significant delays is another limitation, as these may vary by risk group. Future research should establish these thresholds and evaluate their impact on patient outcomes. Additionally, our dataset lacked detailed biopsy information, such as MRI or TRUS use, which may influence Gleason upgrading.

In conclusion, our study highlights the multifaceted nature of treatment delays in prostate cancer during the COVID-19 pandemic. Sociodemographic factors, facility characteristics, and insurance status were all significantly associated with delays, underscoring the need for targeted interventions. As healthcare systems continue to recover from the pandemic, developing strategies that ensure equitable, timely access to cancer care - particularly for vulnerable populations - is essential. Future research should focus on making cancer care more resilient to disruptions and understanding the long-term impact of treatment delays.

Disclosure of conflict of interest

None.

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