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Trends in the Incidence of Fatal Prostate Cancer in the United States by Race

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Abstract

Background—Prostate-specific antigen (PSA) testing has dramatically changed the composition of prostate cancer, making it difficult to interpret incidence trends. New methods are needed to examine temporal trends in the incidence of “clinically significant” prostate cancer, and whether trends vary by race.

Objective—To conduct an in-depth analysis of incidence trends in “clinically significant” prostate cancer, defined as cases in which prostate cancer was the underlying cause of death within 10-years of diagnosis.

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Design, Setting and Participants—We extracted incident prostate cancer cases during 1975–2002, as well as associated causes of death and survival through 2012, from 9 cancer registries in the population-based Surveillance, Epidemiology, and End Results program database.

Measurements—We applied joinpoint regression analysis to identify when significant changes in trends occurred and age-period-cohort models to examine longitudinal and cross-sectional trends in the incidence of fatal prostate cancer.

Results and Limitations—Among 51,680 fatal prostate cancer cases, incidence increased 1% per year prior to 1992, declined 15% per year from 1992–1995, and further declined by 5% per year through 2002. Age-specific incidence rates of fatal disease decreased over 2% per year among men <60 years, yet rates remained relatively stable among men ≥55 years. Fatal disease rates were more than 2-fold higher in black men compared with white men, a racial disparity that increased to 4.2 fold among younger men.

Conclusions—The incidence of fatal prostate cancer has substantially declined after widespread PSA screening and treatment advances. Yet, rates of fatal disease among younger men have remained relatively stable, suggesting the need for additional attention on early-onset prostate cancer, especially among black men. The persistent black-to-white racial disparity observed in fatal prostate cancer underscores the need for a greater understanding of the causes for this difference so that strategies may be implemented to eliminate racial disparities.

Keywords

cancer trends; cause-specific mortality; disease progression; prostate cancer; prostate-specific antigen

Introduction

Prostate cancer is the most frequently diagnosed cancer among men in the United States (US), with 180,890 estimated new cases for 2016.[1] Despite notable improvements in prostate cancer mortality rates in the US over the last few decades,[2] it is estimated that 26,120 men (8% of male cancer deaths) will die from this disease in 2016.[1] Racial disparities in prostate cancer are higher than for any other malignancy, with black men exhibiting a 2.5 fold greater risk of death from prostate cancer compared with white men. [1,3]

There has been a substantial increase in prostate cancer incidence rates in the US over the last few decades largely due to the increased detection of asymptomatic disease, first through transurethral prostatectomy (TURP) for benign prostatic hyperplasia,[4] which was followed by widespread prostate-specific antigen (PSA) testing beginning in 1986.[5,6] The subsequent decrease in prostate cancer incidence rates, attributed to depletion of the latent prostate cancer reservoir in the population, rendered the now-familiar “spike” in overall prostate cancer incidence rates.[6]

Accurate interpretation of “clinically significant” prostate cancer incidence trends has been difficult due to the high prevalence of indolent disease and changes in screening practices. A majority of studies examining prostate cancer trends have focused on the date of death

(mortality rate) as opposed to date of diagnosis,[7,8] the latter of which is a more applicable time metric when assessing disease trends during a period of clinical change. In addition, no study in the last decade has examined trends using age-period-cohort analysis,[9] likely because of unstable parameters resulting from the prostate cancer incidence rate “spike”.

To overcome these problems and provide for an in-depth analysis of “clinically significant” prostate cancer incidence trends and racial disparities, we assessed trends in the incidence of fatal prostate cancer defined as death from this disease within 10 years of diagnosis.[10]

Materials and methods

We obtained census population estimates, cancer incidence, mortality and survival data for calendar years 1975 to 2012 from the National Cancer Institute’s Surveillance, Epidemiology and End Results (SEER) 9 registries, which covers ~10% of the US population. We selected incident cases diagnosed with prostate cancer [International Classification of Diseases for Oncology, third edition, code C619] as their first primary malignant cancer from 1975 (the first year all SEER-9 registries were operational) through 2002. Men were excluded if diagnosis was based on autopsy reports or death certificate only (N=4,137), follow-up time was unknown (N=890), or age at diagnosis was missing (N=15). Men were defined as fatal prostate cancer cases when prostate cancer was the underlying cause of death within 10 years of diagnosis (follow-up through 2012). The 10-year window was selected *a priori* based on empirical evidence from SEER data (80% of all prostate cancer-specific deaths were captured) and literature review.[10,11]

We calculated age-standardized incidence rates and age-specific incidence rates per 100,000 person-years. We conducted joinpoint analysis to identify when statistically significant changes in trends occurred and estimated the annual percentage change in rates between joinpoints using weighted least squares.[12] Age-period-cohort models of fatal prostate cancer were conducted to further examine temporal trends by year of diagnosis, and distinguish between influences that occurred in specific time periods for all age groups (period effects) versus effects associated with specific birth cohorts (generational effects). [13,14] For these models, data were classified into 40 one-year age groups (45–84), 28 one-year calendar periods (1975–2002), and 66 one-year birth cohorts (1891–1956). We fitted cross-sectional age-specific rates based on the central 1988 calendar year. We calculated black-to-white incidence rate ratios to examine racial disparities by period and age at diagnosis (5-year weighted average age groups).[14] Lastly, we used a quadratic spline to fit instantaneous hazard rates of death from prostate cancer (percentage dying of prostate cancer per year among all prostate cancer cases), stratified by race and year of diagnosis (1975–1988 vs. 1989–2002).

In sensitivity analyses, we evaluated shortened (5-years) and extended (15-years) follow-up for cause-specific mortality in order to assess whether competing risks and lead-time bias impacted trends. We also evaluated variable lead-time, where we extended follow-up to 15 years in the PSA era. To evaluate the robustness of our models we: a) included men with metastatic disease in our case definition, b) limited the case pool to men for whom prostate cancer was the sole cancer diagnosis, c) expanded the case pool to include all men diagnosed

with prostate cancer regardless of cancer sequence, d) used predicted 10-year probabilities of death due to prostate cancer for men who died of other causes of death, and e) concatenated SEER 9, 13 and 18 databases.

Statistical analyses were performed in Matlab version R2014b (The MathWorks, Inc., Natick, MA, USA). All statistical tests were two-sided and *P* values less than 0.05 were considered statistically significant.

Results

Of the 309,289 men diagnosed with prostate cancer during 1975–2002, fatal prostate cancer accounted for 17% (N=51,680) of the cases. A total of 222,321 (72%) men with prostate cancer died from any cause during any period of follow-up, and 150,565 of these deaths (68%) occurred within 10-years of prostate cancer diagnosis. During the 10-year period following diagnosis, prostate cancer was the most common cause of death (34%), followed by ischemic heart disease (24%) and cerebrovascular diseases (5%).

Fatal Prostate Cancer Trends

Trends in age-standardized incidence rates of fatal prostate cancer are shown in Figure 1A. Joinpoint regression analysis of trends by year of diagnosis identified two joinpoints, in 1992 and 1995 (Table 1), which indicated rates of fatal prostate cancer increased 1.0% per year from 1975–1992, declined 15.0% per year during the subsequent three-year period (1992–1995), and steadily declined by 5.0% per year through 2002. Age-specific rates of fatal prostate cancer by year of diagnosis exhibited differences between older and younger men, such that rates among younger men appeared relatively stable, whereas rates in older men (> 55 years) revealed a declining trend beginning in the early 1990's (Fig. 1B).

Age-period-cohort models for fatal prostate cancer were successfully fit. Age-specific annual percent changes were heterogeneous (two-sided Wald test: $\chi^2=166.3$, $df=40$, $P<0.0001$) when compared with the overall annual percent change of -1.77% per year. Rates among younger men (< 52 years) increased by up to $0.6\%/year$, while rates decreased for older men (> 61 years) by over $2\%/year$ (Supplementary Figure 1). Period rate ratios demonstrated a significant decline in risk of fatal disease with calendar year (Wald test: $\chi^2=1800.11$, $df=26$, $P<0.0001$) (Supplementary Figure 2).

Racial Disparities in Fatal Prostate Cancer

There were 42,112 fatal cases among white men (81.5%) and 7,434 fatal cases among black men (14.4%). Black men had an earlier mean age at diagnosis (69.1 years vs. 71.1 years) and slightly shorter mean survival among those who died within 10-years (44.4 months vs. 48.4 months) (Supplementary Table 1).

Temporal trends in rates of fatal prostate cancer among both black and white men (Fig. 2A) displayed no evidence of heterogeneity (Wald test: $P=0.16$). Age-period-cohort analysis indicated a period effect in the early 1990s for both black and white men. The black-to-white rate ratios revealed no improvements in the racial disparity of fatal prostate cancer incidence over the last few decades (Fig. 2B), with black men remaining at a consistently 2.2–3.0 fold

elevated risk of fatal disease. Additionally, cross-sectional rates by age at diagnosis revealed a greater racial disparity among younger men (ages <55 years) compared with older men (Fig. 3A: Wald test, $\chi^2=27.6$, $df=1$, $P<0.001$). Rates of fatal prostate cancer were 2-fold greater among older black men compared with older white men (ages 60+ years), a racial difference that increased to 4.2 fold among younger men (ages 45–49 years) (Fig. 3B).

We calculated annual hazard rates of prostate cancer-specific death among all men diagnosed with prostate cancer, stratified by race and period (Figure 4). During the pre-PSA era (1975–1988), the instantaneous hazard of prostate cancer death was significantly higher for black men compared with white men, yet the hazard curves were approximately parallel reaching their peak (black: 8.5%/year, white: 5.5%/year) 1–1.5 years after diagnosis. In contrast, annual hazard rates of prostate cancer death were greatly reduced during the PSA era, yet black men retained higher instantaneous hazards and reached their peak earlier (1.5 years post-diagnosis) compared with white men (2.5 years).

In our sensitivity analysis that assessed shorter-term follow-up (5 years) for determination of cause-specific mortality, trends were virtually unchanged (Supplementary Figures 4 and 5). This indicates that the trends observed in the main 10-year analysis are not due to competing risks. Longer-term follow-up (15 years) to define fatal prostate cancer provided almost identical to our main analysis, suggesting lead-time bias during the pre- and post-PSA eras did not substantially impact results. Analyses that included variable lead-time (extended follow-up of 15 years only within the PSA era) and metastatic prostate cancer did not materially change the trends and disparities observed (Supplementary Figures 6–13). For all remaining sensitivity analyses, trends were also essentially unchanged from the main analyses presented (*data not shown*).

Discussion

This study revealed a substantial decline in the incidence of fatal prostate cancer among US men during the period 1975–2002, yet rates among younger men remained relatively stable over the study period. Our study showed that black men had substantially greater risk of fatal prostate cancer than white men in every period and cohort examined, and this racial disparity was magnified amongst younger men.

Prior studies that have examined trends in prostate cancer mortality,[7–9,11]—as opposed to incidence—are likely more accurate in describing the changing burden of disease given large artifactual changes in incidence attributable to diagnostic tests. The debate continues as to what extent declines in mortality rates since 1991 are attributable to period effects such as the advent of PSA testing,[15] since lead-time introduced through earlier detection has obscured trends.[16] By using the hard endpoint of prostate cancer death and a fixed follow-up period for cause (prostate)-specific mortality, we have been able to conduct an in-depth analysis of “clinically significant” incidence trends based upon calendar year of diagnosis as the time metric. Our approach supports and extends previous analyses of prostate cancer mortality trends and metastatic/distant stage incidence trends, which evidence declining rates of ~50% since the early 1990s [15,17,18]

Men with prostate cancer are at a much greater risk of dying from a cause other than their malignancy, and the percentage of men who die from prostate cancer decreases with increasing time since diagnosis.[11] The rise and fall of US prostate cancer mortality rates is likely the result of a variety of factors including: real changes in disease trends, TURP,[4] PSA testing,[6] advances in treatment modalities,[19] changes in lead-time,[16] and accuracy of cause-specific mortality.[17] While our study cannot tease-out the specific contribution of each period effect to temporal changes observed in the incidence of fatal prostate cancer, our comprehensive study of “clinically significant” disease supports the idea that the majority of the decline in the incidence is likely due to a combination of improved detection and treatment advances.

This study shows that black men were consistently at greater risk in every period and cohort examined, and race-specific models of fatal prostate cancer revealed nearly parallel trends in age, period and cohort effects. Recent studies of prostate cancer mortality in the US have shown the black-to-white disparity beginning to narrow over the last decade,[20] yet studies prior to 2007 had reported that the racial disparity was rising.[21] In our study, in which we have assessed the incidence of fatal prostate cancer through 2002, we observed no improvement in the black-to-white disparity over the 28-year period examined.

The black-to-white disparity in “clinically significant” prostate cancer is poorly understood. Access to care has been postulated as a contributing cause of the racial disparity, yet black and white men have had approximately equal prevalences of PSA testing,[22,23] and racial differences long preceded the PSA era. However, recent evidence has found that black race and low-income are associated with lower rates of aggressive treatment of prostate cancer among men with localized/regional disease.[24] Thus, further research on the impact of differences in treatment by race will aid in providing insight on racial disparities in survival. Genetics and the tumor microenvironment may explain a majority of racial disparities seen in prostate cancer.[25,26] Fine-mapping in men of African ancestry in the 8q24 region, which is known to harbor multiple prostate cancer susceptibility risk variants, has identified three new ancestry-specific risk variants.[27]

In 2016, over 10% of incident prostate cancer diagnoses are expected to occur in men less than 55 years of age,[1] and men with early-onset disease have a different clinical profile and typically a stronger genetic component.[28] To our knowledge, only one study to-date has observed the heightened racial disparity among younger men, which found a 4.9 times greater risk of advanced/metastatic prostate cancer in younger black men compared with white men (ages 40 to 49 years).[29] Our results support this finding—we observed that the black-to-white racial disparity in fatal prostate cancer increased to 4.2 times among younger men (ages 45–49 years). In addition, it is notable that rates of fatal prostate cancer among younger men have remained relatively stable even after the introduction of PSA testing, which may be related to low PSA testing utilization among these age groups.[30] Future studies should strive to provide additional attention on early-onset prostate cancer, as rates of fatal disease among younger men do not appear to be declining. Age-specific and race-specific trends in “clinically significant” prostate cancer may help shape future screening guidelines.

Strengths of this study include the length of the study period, quality of the registry data, and the availability of a large number of cases from a representative, regionally diverse population in the US. Additionally, we complemented standard descriptive methods with age-period-cohort models. Limitations include the typical caveats associated with registry-based descriptive studies (missing data, lack of case-specific risk factors), and assumptions inherent to age-period-cohort models (the nonidentifiability issue). Our use of 10 years of follow-up to determine fatal disease status may not be long enough to completely eliminate lead-time bias, or nullify calendar period shifts in lead-time attributable to changes in diagnostic practices. However, sensitivity analyses using extended and variable follow-up periods provided similar results to our main analysis.

Conclusions

Incidence rates of fatal prostate cancer in the US have declined by over 50% during since the early 1990's, which coincide with diagnostic and treatment changes, yet rates among younger men have remained relatively stable. Robust risk triaging strategies are needed to help further reduce prostate cancer cases that ultimately result in fatal disease, and to limit undue anxiety and over-treatment of individuals with prostate cancer that will not progress. The racial disparity in fatal prostate cancer persists, and the size of this disparity—particularly among younger men—is a call for us to redouble our efforts to elucidate causes and enact strategies to eliminate the disparity.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Patient summary

In this report, we assessed how the incidence of prostate cancer that is ultimately fatal has changed over time. We found that the incidence of fatal prostate cancer declined by over 50% since the introduction of PSA testing and advances in treatment options. However, incidence rates among younger men have remained relatively stable, and younger black men exhibit a 4.2 fold higher risk for fatal disease compared with white men.

Figure 1.

Temporal trends in age-standardized and age-specific incidence rates of fatal prostate cancer, ages 45–84 years, 1975–2002, United States (SEER-9).

A) Age-standardized incidence rates of fatal prostate cancer among all men; B) Age-specific incidence rates of fatal prostate cancer by year of diagnosis (5-year age groups). Age-standardized rates are plotted on the log scale and are age-adjusted to the 2000 US standard population. All age-specific incidence rates are plotted on the log scale.

Figure 2.

Temporal trends in age-standardized incidence rates of fatal prostate cancer among black and white men by year of diagnosis and corresponding black-to-white rate ratios, ages 45–84 years, 1975–2002, United States (SEER-9).

A) Fitted temporal trends in the incidence of fatal prostate cancer with scatter points for black (yellow squares) and white (blue circles) men; B) Black-to-white period-specific rate ratios in the incidence of fatal prostate cancer, adjusted for non-linear cohort effects and conditioned upon age at diagnosis (64 years). The age-standardized incidence rates among black and white men are plotted on the log scale.

Figure 3.

Cross-sectional age-specific incidence rates of fatal prostate cancer among black and white men and corresponding black-to-white rate ratios (5-year age group weighted averages), ages 45–84 years, 1975–2002, United States (SEER-9).

A) Cross-sectional age-specific incidence rates of fatal prostate cancer among black (yellow squares) and white (blue circles) men, adjusted for non-linear cohort effects and conditioned upon the 1988 central calendar year of diagnosis; B) Black-to-white age-specific (5-year age group weighted averages) rate ratios in the incidence of fatal prostate cancer. The cross-sectional age-specific incidence rates are plotted on the log scale.

Figure 4.

Annual hazard rates of death due to prostate cancer as the underlying cause of death (percentage of prostate cancer cases dying each year following diagnosis) stratified by race and calendar period, ages 45–84 years, 1975–2002, United States (SEER-9). Hazard rates are plotted for all prostate cancer cases among white and black men. The period 1975–1988 is classified as the pre-PSA era and the period 1989–2002 as the PSA era.

Table 1

Annual percentage changes in age-standardized incidence rates of fatal prostate cancer over the entire study period and for sub-periods defined from joinpoint analysis by race, ages 45–84 years, 1975–2002, United States (SEER-9).

Race	Year	Annual Percent Change [#]	95% CI
All Races	All years	–2.44 *	–3.27 to –1.61
	1975–1992	1.02 *	0.72 to 1.32
	1992–1995	–14.99 *	–21.86 to –7.51
	1995–2002	–4.95 *	–6.02 to –3.88
White	All years	–2.55 *	–3.38 to –1.71
	1975–1992	0.97 *	0.61 to 1.33
	1992–1994	–18.67 *	–18.68 to –18.66
	1994–2002	–5.54 *	–6.00 to –4.47
Black	All years	–1.97 *	–2.90 to –1.02
	1975–1993	1.45 *	0.83 to 2.07
	1993–1995	–19.48 *	–19.49 to –19.48
	1995–2002	–5.93 *	–8.31 to –3.50

[#] Annual percent changes were calculated using the weighted least squares method.

* The annual percent change is significantly different from zero, *P* less than .05 (two-sided permutation test).