ORIGINAL REPORT

Does a Recent Cancer Diagnosis Predict Smoking Cessation? An Analysis From a Large Prospective US Cohort

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See accompanying editorial on page 1631

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A B S T R A C T

Purpose
Quitting smoking provides important health benefits to patients with cancer. A cancer diagnosis may motivate quitting—potentially providing a teachable moment in which oncologists can encourage and assist patients to quit—but little is known about whether a recent cancer diagnosis (including diagnosis of a cancer that is less strongly linked to smoking) is associated with increased quitting.

Methods
Cancer Prevention Study-II Nutrition Cohort participants reported smoking status at enrollment in 1992 to 1993 and approximately biennially through 2009. Quit rates of smokers diagnosed with cancer during 2- and 4-year intervals were compared with those of smokers not diagnosed with cancer (12,182 and 12,538 smokers in 2- and 4-year analyses, respectively). Cancers likely to cause physical limitations or symptoms that could influence smoking (cancers of the lung, head and neck, esophagus, or any metastatic cancer) were excluded. Logistic regressions calculated quit rates controlling for age, sex, survey year, cardiovascular disease, and chronic obstructive pulmonary disease.

Results
The 2-year quit rate was higher among the 772 smokers who were diagnosed with cancer (31.3%; 95% CI, 28.0% to 34.5%) than among smokers not diagnosed with cancer (19.5%; 95% CI, 19.0% to 19.9%). A similar difference was observed for 4-year quit rates (43.0% v 33.8%). Results were similar by cancer site and stage.

Conclusion
A diagnosis of cancer, even a cancer not strongly related to smoking and with a relatively good prognosis, may be associated with increased quitting that is sustained well after diagnosis. Results support the hypothesis that a cancer diagnosis presents a teachable moment that can be capitalized on to promote cessation.

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INTRODUCTION

Smoking is a risk factor for many cancers,[1] but some survivors continue to smoke after diagnosis. Among the estimated 13.7 million cancer survivors alive today in the United States,[2] the prevalence of smoking is estimated to vary between 15% and 33%, depending on the type of cancer, age, and time since diagnosis.[3-6] Smoking has many adverse health effects other than cancer, and for cancer survivors smoking also increases the risk of second primary smoking-associated cancers (eg, lung cancer) and cancer-specific mortality.[7] Smoking has also been associated with poorer response to cancer treatment and cancer recurrence.[7]

Recent research has raised the idea that for smokers, receiving a cancer diagnosis can be a teach-able moment, an advantageous time to discuss smoking and provide cessation assistance because patients may be more motivated to quit and thus be more receptive to cessation intervention.[8,9] The idea that a cancer diagnosis is a teachable moment for smoking cessation would be strengthened if it could be shown that smokers recently diagnosed with cancer are more likely to quit than smokers without cancer.

Relatively few studies have compared rates of smoking cessation between individuals with and without a recent cancer diagnosis.[10-13] Although results of these studies suggest higher quit rates among those recently diagnosed, conclusions are limited as a result of the relatively small size of the studies. Moreover, a recent United Kingdom study[12] found no significant difference in quit rates 0 to 2 and 2 to 4 years

after diagnosis between individuals diagnosed with cancer and a comparison group, although this study included only approximately 50 smokers diagnosed with cancer.

With the exception of a study of 60 patients with bladder cancer,[11] most studies examining the association between cancer diagnosis and smoking cessation included all individuals diagnosed with cancer, regardless of site or stage at diagnosis. However, quitting among patients diagnosed with metastatic cancer or with cancers of the esophagus, head and neck, or lungs may be influenced by immediate physical symptoms and limitations caused by their cancer that make it more difficult to smoke. Quitting among patients with other cancers may be more motivated by a desire to reduce disease risk.

In this analysis we used data from a large prospective study, the Cancer Prevention Study (CPS) -II Nutrition Cohort, to examine the hypothesis that a recent cancer diagnosis is associated with a higher rate of quitting, even when the cancer diagnosis is not likely to be immediately life threatening or to produce physical symptoms that discourage smoking. The CPS-II Nutrition Cohort is well suited to examine this hypothesis because of its large size and because information on both new cancer diagnoses and smoking status was ascertained approximately every 2 years for more than 17 years.

METHODS

Study Design and Participants

The CPS-II Nutrition Cohort, described in detail elsewhere,[14] was established in 1992 and included more than 184,000 US men and women, predominantly older than age 50 years at enrollment. Between 1992 and 1993, at enrollment, participants completed a mailed survey with questions assessing demographic, medical, lifestyle, and cigarette smoking variables. Follow-up surveys were completed beginning in 1997 and every 2 years thereafter (biennially) to update information on smoking and other risk factors and to ascertain newly diagnosed cancers. The response rate for each follow-up questionnaire was at least 87%. Cancer diagnoses were identified through self-report or linkage with the National Death Index and were subsequently verified through medical records or state cancer registries.[14,15] All aspects of the study design received Human Subjects approval through the Emory University Institutional Review Board.

CPS-II Nutrition Cohort participants were eligible for analyses of smoking quit rates 2 and 4 years after diagnosis if they did not have a history of cancer at enrollment in 1992 or 1993, reported current smoking on at least one questionnaire, and reported smoking status on at least one subsequent questionnaire within 4 years. Respondents missing smoking status data at the beginning or end of an interval (intervals were based on survey years) were not included in analyses for that interval. The proportion of respondents who reported current smoking at the beginning of a 2-year interval but who did not report smoking status at the end of the interval was 15%.

Assessment of Smoking Status

At enrollment in 1992 or 1993, and on follow-up surveys in 1997 and every 2 years thereafter, participants were asked whether they were currently smoking cigarettes (yes *v* no). Because of the 5-year gap between the 1992 and 1997 questionnaires (compared with the 2-year gap between subsequent surveys), we used information from the 1997 questionnaire to establish smoking status at the approximate midpoint of this period, specifically July 1, 1995. Current smokers on both the 1992 and 1997 questionnaires were counted as current smokers on July 1, 1995. Those who reported being former smokers on the 1997 questionnaire were asked to report when they last quit using categories of "less than 1 year ago," "1 to 2 years ago," "3 to 5 years ago," and "more

than 5 years ago." This information was used to assign former or current smoking status on July 1, 1995. Assigned smoking status in 1995 was then used in 2- and 4-year quit rate analyses as if it had been reported on a biennial questionnaire.

Statistical Analysis

Two separate quit rates were calculated: a 2-year quit rate, on the basis of reports of smoking or quitting from two consecutive questionnaires (eg, 1997 and 1999), and a 4-year quit rate, on the basis of questionnaires two cycles apart (eg, 1997 and 2001). We did not examine longer-term quit rates because we expected the influence of a cancer diagnosis on smoking cessation to diminish as time since diagnosis increased.

Smokers could contribute more than once to quit rate calculations, for example, as a nonquitter in an interval between two consecutive questionnaires, but as a quitter in the next interval. Therefore, the unit of observation in all analyses was defined as a person-quit interval (PQI). Each PQI is a person-time interval starting with current smoking and ending with an outcome of either continued smoking or quitting. Thus, for calculation of 2-year quit rates, the quit rate was defined as the proportion of 2-year PQIs that began with smoking but ended in quitting. Similarly, for 4-year quit rates, the quit rate was defined as the proportion of 4-year PQIs that began with smoking but ended in quitting. After contributing a PQI as a cancer-diagnosed smoker, a participant could not contribute subsequent PQIs. In the 4-year analysis, individuals were allowed to contribute only nonoverlapping PQIs. For example, an individual could contribute a PQI for the interval between completion of the 1997 and 2001 questionnaires, and another PQI for the interval between completion of the 2001 and 2005 questionnaires, but could not contribute a PQI for the interval between completion of the 1999 and 2003 questionnaires. The specific calendar years of PQIs contributed could differ by participant. For example, a participant with missing smoking data in 1992 would have contributed a first PQI for the interval from 1995 to 1999, and a second PQI for the interval from 1999 to 2001.

To reduce the chance that quitting preceded diagnosis or that quitting was influenced by cancer treatment, analyses of 2-year quit rates excluded all PQIs that included a cancer diagnosis within 6 months of the end of each 2-year interval. They also excluded PQIs during which respondents received a diagnosis of cancer of the lung, head and neck, esophagus, or of metastatic cancer at any site (n = 263; quit rates were more than 50% for these individuals). After these exclusions, a total of 12,182 participants contributed PQIs to the 2-year quit rate analyses, yielding 772 PQIs that included a cancer diagnosis (each from a different participant) and 39,467 PQIs that did not.

Analyses of 4-year quit rates used similar exclusions as those of 2-year quit rate analyses, but excluded all PQIs that included a cancer diagnosis in the second half of the 4-year interval (rather than in the last 6 months of the PQI, as in the 2-year analysis). This exclusion reduced the chance that quitting preceded diagnosis. After exclusions, a total of 12,538 participants contributed PQIs to this analysis, yielding 900 PQIs that included a cancer diagnosis and 22,113 PQIs that did not.

In calculating quit rates, unadjusted rates were first estimated separately for smokers who were diagnosed with cancer and compared with those of smokers who were never diagnosed with cancer. Logistic regression modeling with SAS 9.4 (SAS Institute, Cary, NC) software was then used to calculate adjusted quit rates, standardized to the covariate distribution of individuals with cancer on age, sex, survey year distribution, chronic obstructive pulmonary disease/cardiovascular disease (COPD/CVD), and the interactions of cancer status with sex and COPD/CVD[16] (additional adjustments for education, marital status, and alcohol and tobacco use variables did not meaningfully alter results). Details of this model and calculation of corresponding CIs are described in the Appendix (online only). Among smokers diagnosed with cancer, quit rates by cancer type and stage were also calculated.

Variables tested as potential modifiers of the association between cancer diagnosis and smoking cessation included sociodemographic variables (age, sex, education, marital status); tobacco and alcohol use variables (age of smoking initiation, No. of years as smoker, cigarettes smoked per day, and No. of drinks per day); and serious health conditions associated with smoking (self-reported diagnosis of COPD or CVD).

Table 1. Baseline Characteristics of Smokers in CPS-II in 1992 by Cancer Diagnosis Status

Characteristic	Cancer Diagnosis* (n = 772), No. (%)	No Cancer Diagnosis* (n = 11,410), No. (%)
Sociodemographic		
Age, years		
< 55	65 (8.4)	1,427 (12.5)
55-59	193 (25.0)	3,287 (28.8)
60-64	262 (33.9)	3,400 (29.8)
65-69	184 (23.8)	2,345 (20.6)
≥ 70	68 (8.8)	951 (8.3)
Sex		
Male	420 (54.4)	5,245 (46.0)
Female	352 (45.6)	6,165 (54.0)
Race		
White	758 (98.4)	11,069 (97.0)
Black	10 (1.1)	203 (1.8)
Education†		
High school or less	260 (33.4)	4,263 (37.3)
Postsecondary	505 (65.6)	7,061 (61.9)
Marital status†		
Not married	85 (12.4)	1,476 (12.9)
Married	675 (86.2)	9,811 (86.0)
Smoking and alcohol use		
Age started smoking, years†		
< 18	331 (42.1)	4,282 (37.6)
≥ 18	383 (50.3)	5,705 (49.9)
No. of years smoked†		
< 45	446 (61.8)	7,017 (61.2)
≥ 45	268 (30.7)	2,973 (26.3)
Cigarettes smoked per day†		
< 20	229 (28.9)	3,856 (33.8)
≥ 20	485 (63.6)	6,134 (53.8)
Alcoholic drinks per day†		
< 1	492 (64.5)	7,858 (68.8)
≥ 1	249 (31.7)	3,063 (26.9)
Health conditions		
Chronic obstructive pulmonary disease†		
No	728 (94.2)	10,799 (94.6)
Yes	44 (5.8)	611 (5.4)
Cardiovascular disease†		
No	714 (93.6)	10,524 (92.2)
Yes	58 (6.4)	886 (7.8)
Cancer site		
Prostate	237 (30.7)	N/A
Breast	194 (25.1)	N/A
Bladder	89 (11.5)	N/A
Colorectal	88 (11.4)	N/A
Other	164 (21.2)	N/A
Age at diagnosis, years		
< 60	69 (8.9)	N/A
60-64	159 (20.6)	N/A
65-69	249 (32.3)	N/A
70-74	194 (25.1)	N/A
≥ 75	101 (13.1)	N/A

NOTE. Data are based on respondents included in 2-year analyses. Subtotals may not equal actual totals because of exclusion of respondents missing data on a particular characteristic.
Abbreviations: CPS, Cancer Prevention Study; N/A, not applicable.
*Cancer diagnosis, or no cancer diagnosis, during follow-up through 2009.
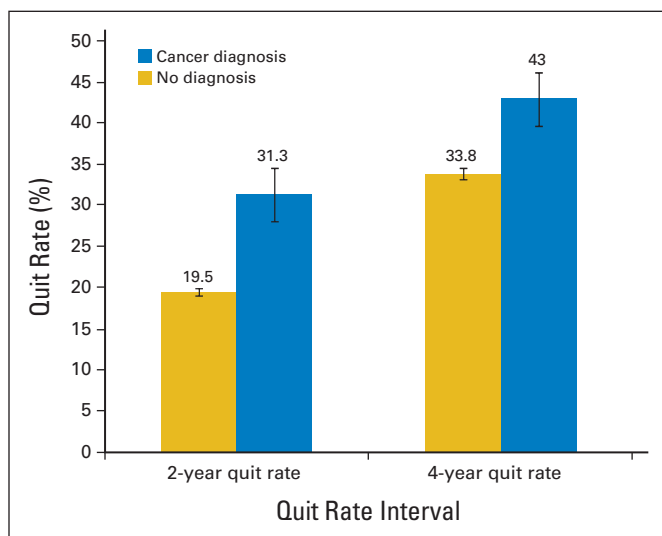†Standardized to the age and sex distribution of the cohort (for this reason P values were not computed).

Fig 1. Comparison between cancer-diagnosed and nondiagnosed smokers with respect to 2- and 4-year quit rates.

RESULTS

Baseline Characteristics

For participants included in 2-year quit rate analyses, Table 1 shows baseline characteristics of those diagnosed with cancer (excluding diagnoses of lung, head and neck, esophageal, and metastatic cancer) and all others. In both groups, participants were predominantly white, older than age 55 years at enrollment, married, and somewhat more likely to have started smoking after age 18. Smokers diagnosed with cancer were slightly more likely to be male and heavier smokers (≥ 20 cigarettes per day). Most diagnoses were cancers of the prostate (30.7%), breast (25.1%), bladder (11.5%), or colorectum (11.4%).

Two-Year Quit Rates

Unadjusted quit rates were higher among smokers who had been diagnosed with cancer (31.3%) compared with those of smokers who had not (19.0%). There was little evidence of confounding, given that adjusted quit rates (31.3% v 19.5%, respectively, on the basis of the logistic regression model; $P < .001$) were similar to the unadjusted rates (Fig 1; Table 2 shows quit rates by 2-year intervals). When PQIs in which a diagnosis occurred within the last 6 months of a 2-year interval were not excluded, the adjusted quit rates remained similar (31.3% among those diagnosed with cancer; 18.5% among those not diagnosed with cancer).

The only significant modifiers were sex ($P = .02$) and health status ($P = .04$; Table 3). Although for both men and women smokers, those diagnosed with cancer had higher quit rates compared with those not diagnosed, the difference was larger among women (33.6% v 17.7%) than among men (28.8% v 21.0%). For smokers who had a serious smoking-related health condition (COPD or CVD), quit rates were relatively similar for those who were later diagnosed with cancer (22.3%) and those who were not (19.1%); in contrast, the difference in quit rates by cancer diagnosis was much larger among individuals who did not have COPD or CVD (33.3% v 19.6%). Two-year quit rates did not seem to differ by stage at which the cancer was diagnosed (Table 3) or by type of cancer (Fig 2).

Table 2. Two-Year Quit Rates by Cancer Diagnosis Within 2-Year Intervals and Over All Intervals in CPS-II Nutrition Cohort

	Cancer Diagnosed*			No Diagnosis		
Interval	Smoking at Start of Interval (No.)	Quit at End of Interval (No.)	Quit Rate, Unadjusted (%)	Smoking at Start of Interval (No.)	Quit at End of Interval (No.)	Quit Rate, Unadjusted (%)
1992/1993-1995	184	67	36.4	10,038	1,582	15.8
1995-1997	194	49	25.3	8,082	1,471	18.2
1997-1999	120	42	35.0	5,849	1,289	22.0
1999-2001	81	19	23.5	4,541	873	19.2
2001-2003	57	21	36.8	3,722	706	19.0
2003-2005	49	13	26.5	3,027	623	20.6
2005-2007	65	21	32.3	2,392	517	21.6
2007-2009	22	10	45.5	1,816	419	23.1
Quit rate over all intervals	772	242	31.3	39,467	7,480	19.0
Adjusted quit rate			31.3†			19.5†
95% CI			28.0 to 34.5			19.0 to 19.9

NOTE. Cancer-diagnosed smokers included in analyses of a particular interval are not included in subsequent intervals.
Abbreviation: CPS, Cancer Prevention Study.
*Diagnosed within each 2-year interval. Excludes those diagnosed with cancer who reported their smoking within 6 months of their cancer diagnosis.
†Standardized on basis of sex, age, survey year distribution, and chronic obstructive pulmonary disease/cardiovascular disease status.

Four-Year Quit Rates

The difference in 4-year quit rates between smokers with a cancer diagnosis and those without a cancer diagnosis was similar to that for 2-year quit rates. Among cancer-diagnosed smokers, the unadjusted 4-year quit rate was 43.0% compared with 33.9% for nondiagnosed smokers. Adjusted rates were 43.0% and 33.8%, respectively (P < .001; Fig 1).

We also examined relapse among participants who quit smoking during the 2-year analyses and completed the two following biennial

Table 3. Association of Cancer Diagnosis With 2-Year Quit Rates by Sex, Health Status, Other Potential Modifiers, and Cancer Stage

	Two-Year Quit Rates		
Modifiers	Cancer Diagnosis, % (95% CI)	No Diagnosis, % (95% CI)	P for Interaction*
Sex			
Female	33.6 (28.5 to 38.3)	17.7 (17.2 to 18.2)	.019
Male	28.8 (24.3 to 33.7)	21.0 (20.3 to 21.6)	
Health status			
No COPD/CVD	33.3 (29.4 to 36.9)	19.6 (19.1 to 20.1)	.041
CVD or COPD	22.3 (16.0 to 28.5)	19.1 (18.1 to 20.1)	
Age, years			
< 65	34.6 (28.6 to 40.5)	18.2 (17.4 to 19.1)	.069
65-< 75	28.3 (23.7 to 32.5)	20.4 (19.7 to 21.0)	
≥ 75	37.5 (26.6 to 48.5)	21.2 (19.3 to 23.3)	
Education			
High school or less	28.1 (22.4 to 33.5)	19.2 (18.5 to 19.9)	.354
Postsecondary	32.9 (28.7 to 37.0)	19.7 (19.1 to 20.2)	
Cigarettes per day			
< 20	35.8 (30.3 to 41.0)	24.2 (23.5 to 24.9)	.260
≥ 20	26.8 (22.7 to 30.7)	14.2 (13.6 to 14.7)	
Smoking duration, years			
< 45	39.2 (33.8 to 44.3)	25.1 (24.2 to 25.8)	.303
≥ 45	25.7 (21.4 to 30.0)	16.6 (16.0 to 17.2)	
Age started smoking, years			
< 18	29.6 (24.9 to 34.7)	18.0 (17.4 to 18.6)	.611
≥ 18	32.4 (27.6 to 36.8)	20.7 (20.1 to 21.3)	
Marital status			
Not married	25.0 (16.4 to 34.8)	16.9 (15.7 to 18.2)	.623
Married	32.6 (28.9 to 36.5)	20.0 (19.5 to 20.5)	
Cancer stage			
In situ/local	30.6 (26.8 to 34.1)	N/A	N/A
Regional	36.5 (28.9 to 44.6)	N/A	N/A
Missing	24.8 (11.7 to 37.7)	N/A	N/A

NOTE. Standardized on basis of sex, age, survey year distribution, COPD/CVD, and interaction of diagnosis status with sex and COPD/CVD.
Abbreviations: COPD, chronic obstructive pulmonary disease; CVD, cardiovascular disease; N/A, not applicable.
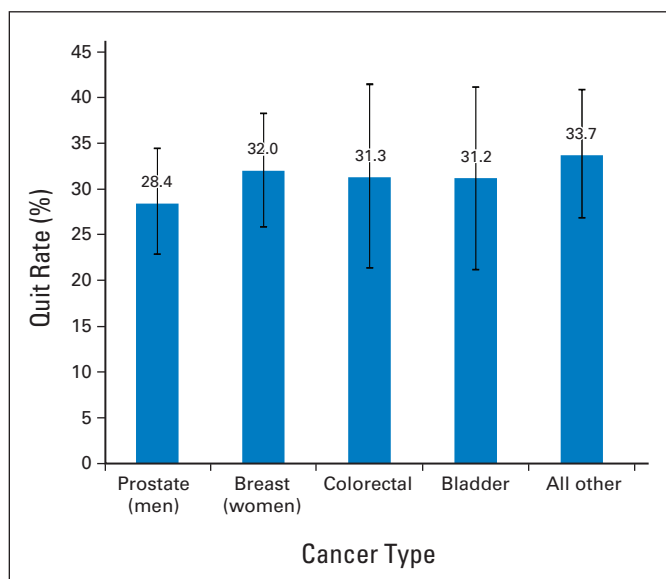*P values based on logistic regression model.

Fig 2. Two-year (adjusted) quit rates among cancer-diagnosed smokers by cancer type.

questionnaires (2 and 4 years after reporting not smoking). Resumption of smoking within 4 years was reported by 12.4% (19 of 153) of individuals who quit during the 2-year interval in which cancer was diagnosed, and by 15.4% (756 of 4,916) of those not diagnosed.

DISCUSSION

In this large prospective study, a cancer diagnosis was associated with significantly higher rates of quitting smoking within both 2 and 4 years of the diagnosis. Almost one in three smokers who received a cancer diagnosis had quit smoking within 2 years, compared with fewer than one in five smokers who had never received a cancer diagnosis. Moreover, the greater quitting rate among cancer-diagnosed smokers was maintained at 4 years, and quit rates did not differ by cancer type.

Our results are qualitatively similar to those observed in the Health and Retirement Study, the largest previous study to present and compare quit rates of individuals with and without a recent cancer diagnosis.[10] In that analysis, 2-year quit rates were 24% among smokers with a cancer diagnosis and 16% among smokers without a diagnosis. Quit rates were somewhat higher overall in our analysis, perhaps because of the older average age of our participants. However, important differences are that the Health and Retirement Study analysis was based on self-reported cancer and did not examine results by type or stage of cancer. In addition, using the detailed information on cancer diagnoses that was available, we were able to restrict analyses to cancers that are less likely to affect the physical ability to smoke or to cause immediate symptoms that might strongly influence smoking cessation. Thus, our results provide evidence that psychological factors, rather than only physical limitations, may contribute to higher quit rates after a cancer diagnosis.

To our knowledge, this is the first analysis to show that even common cancer diagnoses that historically have not been considered to be smoking related (eg, breast cancer[7]) are associated with higher quit rates. A cancer diagnosis may have operated as a cue to action among smokers that led them to attempt to reduce their future cancer-

related risk or more generally to improve their health. In addition, patients' oncologists or health care providers may have recommended that they quit smoking and/or provided cessation support. However, a study of patients with lung cancer found that although many oncologists do ask patients about smoking and quitting—and are supportive of providing cessation assistance to patients with cancer who smoke—in practice, their provision of cessation assistance and follow-up on smoking status is low.[17,18] Moreover, the likelihood that quitting would be recommended for patients with cancers not historically considered to be smoking related may be even lower. However, individuals in the social network of a patient with cancer, for example, his or her spouse, may motivate, promote, or support quitting, although there is scant research on this topic.[19-21]

We observed that the relationship between cancer diagnosis and increased quitting, although present for both men and women, was even more pronounced in women smokers. There may be several reasons for this—for example, women may be more motivated by health threats to change their behavior[22,23]—but the sex difference we observed requires replication.

We also observed that although a diagnosis of cancer led to greater quitting among smokers without COPD or CVD before diagnosis, a cancer diagnosis did not have a clear influence on quitting rates among smokers already diagnosed with COPD or CVD. Individuals with COPD/CVD who continue to smoke after a diagnosis may be highly tobacco dependent and/or they may be generally less likely to make behavior changes for health-related reasons (eg, they may fatalistically believe that quitting will not change their risk). Future research should examine possible reasons behind low rates of quitting after cancer diagnosis among those with preexisting chronic conditions that are linked to smoking.

A strength of this analysis is its large size. To our knowledge, this is the largest study of this topic to date. In addition, detailed information was available that enabled us to examine results by cancer site and stage and to restrict analyses to cancer diagnoses that are less likely to have immediate physical effects. A limitation is that we did not have the exact dates that smokers quit. Therefore, it is likely that within 2- or 4-year quit intervals, some individuals had already quit smoking before their cancer diagnosis, which could have attenuated the association we observed between cancer and quitting. However, we reduced the potential for such attenuation by excluding cancers diagnosed in the last 6 months of a 2-year interval, or in the last half of a 4-year interval. Smokers in the current study were also predominantly white, older than age 50 years, and on average, better educated than similarly aged smokers in the general population. However, the association between cancer diagnosis and smoking cessation was observed even among less educated participants. Results should be generalized with caution to other racial, ethnic, or age groups. Biochemical validation was not conducted, but the likelihood of misrepresentation of smoking status in a nonclinical study is small.[24]

Our finding that a recent cancer diagnosis may motivate smoking cessation supports the idea of a cancer diagnosis as a teachable moment, when smoking cessation interventions, such as behavioral treatment and/or pharmacotherapy, could be particularly efficacious. Results of this study therefore support the recent recommendation of the American Association of Cancer Research that all patients with cancer who use tobacco be provided with evidence-based tobacco

cessation assistance.[25] Clinicians can capitalize on this potential teachable moment by discussing a patient's desire to quit, giving information about the available options for cessation treatment, affirming the benefits of quitting, and providing resources for follow-up tracking and support. Communicating to patients with cancer that others like them use their diagnosis to motivate themselves to quit, and that many are successful in doing so, may also encourage quitting, although this approach would need to be tested in future research. Effective behavioral treatments have been developed for cancers that are strongly associated with smoking, such as lung cancer or head and neck cancer,[26] but more research is needed on smoking cessation interventions among smokers with cancers that are not strongly linked to smoking.

In conclusion, our results indicate that smokers who have been recently diagnosed with cancer may be substantially more likely to quit smoking than other smokers, even when the cancer diagnosis is not strongly smoking related and is unlikely to be causing serious physical symptoms that would limit or discourage smoking. Our results suggest that smokers may be primed to quit smoking after a diagnosis of any type of cancer, and therefore, that this time period may offer oncologists and other health care providers a particularly valuable opportunity to increase smoking cessation among cancer survivors.

AUTHORS' DISCLOSURES OF POTENTIAL CONFLICTS OF INTEREST

Disclosures provided by the authors are available with this article at www.jco.org.

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Appendix

The quit rate, more precisely the 2- or 4-year probability of quitting, was calculated as Rate $= \exp(\alpha 0 + \alpha 1{*}Ca + \alpha 2{*}Cov)/(1 + \exp(\alpha 0 + \alpha 1{*}Ca + \alpha 2{*}Cov))$, where the α values represent parameter estimates and Cov represents the covariates (including age), and exp() is the exponential function. These model-predicted quit rates were then standardized as described by Wilcosky et al (J Chronic Dis 38:849-856, 1985). Approximate CIs for these standardized, model-based proportions were calculated using bootstrapping as suggested by Greenland (Am J Epidemiol 160:301-305, 2004; 1,000 resampled datasets). Quit rates, based on each of the 1,000 models, were averaged to calculate final CIs.