

Electronic Cigarette Use among Survivors of Smoking-Related Cancers in the United States

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Abstract

Background: The prevalence of electronic cigarette (e-cigarette) use and its impact on smoking cessation among cancer survivors in the United States is largely unknown. We sought to estimate the prevalence of e-cigarette use and examine its associations with cigarette smoking and smoking quit attempts among smoking-related cancer survivors in the United States.

Methods: We obtained data from the 2014–2017 annual cycles of the National Health Interview Survey for participants with self-reported history of smoking-related cancer(s). We calculated the prevalence of current e-cigarette use and utilized multinomial logistic regression in examining the independent association between e-cigarette use and cigarette smoking. Appropriate survey weights were applied in estimating the prevalence rates, relative risk ratios (RRR), ORs, and confidence intervals (CI).

Results: Our sample comprised 3,162 smoking-related cancer survivors. The prevalence of current e-cigarette use was 3.18% (95% CI, 2.40–3.96). Current e-cigarette users were 83 times as likely as never users to be current cigarette smokers (RRR, 82.89; 95% CI, 16.54–415.37). Among those with a history of cigarette smoking, current e-cigarette users were 90% less likely to be former smokers (OR, 0.10; 95% CI, 0.05–0.18). No association was seen between current e-cigarette use and a smoking quit attempt in the prior year.

Conclusions: E-cigarette use among cigarette ever smokers was associated with a lower likelihood of being a former smoker/having quit smoking, and e-cigarette use was not associated with smoking quit attempts.

Impact: Our findings do not provide evidence that e-cigarette use facilitates smoking cessation among smoking-related cancer survivors.

Introduction

Smoking cessation improves the prognosis of patients with cancer, reduces the risks of continued smoking on treatment-related toxicity, cancer recurrence, second primary cancers, and improves the quality of life and survival among patients with both tobacco-related and nontobacco-related malignancies (1). Smoking cessation is therefore advised for all patients with cancer and survivors across all stages of their disease course and survivorship (1).

Given the uptake in the use of electronic cigarettes (e-cigarettes) in the United States (U.S.) general population, with recent adult prevalence as high as 5% in 2016 (2–5), and the marked reduction in exposure to carcinogens found in combustible cigarettes (6, 7), some have speculated about the prevalence of e-cigarette use and potential cessation benefits for its use among patients and survivors with cancer. Although there have been some findings

reported from small studies (8, 9), the national prevalence of e-cigarette use among cancer patients and survivors in the United States, specifically those with a history of smoking-related cancers, is unknown. Similarly, there is a paucity of data on the association between e-cigarette use, smoking quit attempts, and smoking cessation in this group. To date, observational studies have not demonstrated that e-cigarette use reduces the rates of tobacco use among patients with prior cancer diagnosis (8, 10).

We therefore sought to estimate the prevalence of current e-cigarette use and examine its associations with cigarette smoking and quit attempts among survivors of smoking-related cancers in the United States. Our specific study objectives were: (i) to estimate the national prevalence of current e-cigarette use among survivors of smoking-related cancers in the United States; (ii) to examine the association of current e-cigarette use with cigarette smoking history among all survivors of smoking-related cancers in the United States; (iii) to examine the association of e-cigarette use with current smoking status among survivors of smoking-related cancers in the United States with a lifetime history of cigarette smoking and; (iv) to examine the association between current e-cigarette use and a history of one or more smoking quit attempts in the prior year among survivors of smoking-related cancers in the United States who report current smoking.

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Materials and Methods

Data source and study population

We obtained data from the publicly available datasets of the National Health Interview Survey (NHIS) for the years 2014 through 2017. The NHIS is conducted as cross-sectional personal interview surveys of heterogeneously sampled U.S. households by

the National Center for Health Statistics (NCHS) of the U.S. Centers for Disease Control and Prevention (CDC) to provide data on the health of the U.S. noninstitutionalized civilian population. The NHIS has been operated since 1957 with interviews conducted continuously throughout the year. Since 1997, the interview questionnaire has comprised two or more sets of questions; one set comprises core questions asked each year that generally remains the same while the other set(s) comprise supplemental questions that vary from year to year. All adults, defined by the NHIS as those 17 years of age and older in sampled households, are personally interviewed by self-report to generate a family core component, after which one randomly selected adult member per family is asked to respond to a sample adult questionnaire by self-report. We utilized data reported from the sample adult questionnaire for the years 2014 to 2017 as well as the cancer supplement questionnaire available in 2015. The NHIS sampling design employs a stratified multistage, area probability sampling technique. Further details regarding the purpose, sampling design, questionnaire contents, and data collection methods of the NHIS are available elsewhere (https://www.cdc.gov/nchs/nhis/about_nhis.htm).

Our study sample comprised adult respondents, aged 18 years and older, with a self-reported history of diagnosis of a smoking-related cancer. The history of having a smoking-related cancer was obtained from participant responses to the following questions: "Have you ever been told by a doctor or other health professional that you had cancer or a malignancy of any kind?" (responses: yes; no; refused; don't know); and "What kind of cancer was it?" [responses: bladder; blood; bone; brain; breast; cervix; colon; esophagus; gallbladder; kidney; larynx-windpipe; leukemia; liver; lung; lymphoma; melanoma; mouth/tongue/lip; ovary; pancreas; prostate; rectum; skin (nonmelanoma); skin (don't know what kind); soft tissue (muscle or fat); stomach; testis; throat – pharynx; thyroid; uterus; other; refused; don't know). Smoking-related cancers were defined as cancers of any of the following organs: bladder, cervix, colon, esophagus, kidney, larynx, liver, lung, mouth/tongue/lip, pancreas, rectum, and stomach, and throat (pharynx)]. These represent solid tumor cancers for which there is sufficient epidemiologic evidence of a causal association with cigarette smoking (1). Although smoking is causally linked with acute myeloid leukemia, it was not specified as a cancer type in the survey (1). Instead, "cancer of the blood" and "leukemia" were the specified cancer types. Acute myeloid leukemia (AML) accounts for 35% of new diagnoses of adult leukemia in the United States (11). Conversely, the majority of respondents with a history of blood cancers and leukemia would have blood cancers, other than AML, for which smoking has not been causally associated. Therefore, we did not include those who self-reported as being patients or survivors of blood cancers and leukemia to minimize misclassification bias that may lead to a mild inflation of the sample size and hence the denominator used in the descriptive analyses.

Variables

E-cigarette use history. E-cigarette use was evaluated by collating responses to the questions: "Have you ever used an e-cigarette even one time?" (responses: yes; no; refused; don't know); and "Do you now smoke e-cigarettes every day, some days, or not at all?" (responses: every day; some days; not at all; refused; don't know). For the descriptive analyses, participants were classified

into one of three mutually exclusive categories: "never e-cigarette users" if they had never used an e-cigarette; or "former e-cigarette users" if they reported ever using an e-cigarette but were not currently using e-cigarettes; or "current e-cigarette users" if they reported ever using an e-cigarette and were currently using e-cigarettes every day or on some days.

Smoking history and quit attempt in the past year. Smoking history was assessed from responses to the set of questions: "Have you smoked at least 100 cigarettes in your entire life?" (responses: yes; no; refused; don't know), and "Do you now smoke cigarettes every day, some days, or not at all?" (responses: every day; some days; not at all; refused; don't know). Participants were defined as "never smokers" if they had a lifetime smoking history of less than 100 cigarettes; or "former smokers" if they reported a lifetime smoking history of more than 100 cigarettes but were not currently smoking; or "current smokers" if they reported a lifetime smoking history of more than 100 cigarettes and were still smoking every day or on some days.

Smoking quit attempt within the past year was assessed from the response to the question: "During the past 12 months, have you stopped smoking for more than one day because you were trying to quit smoking?" (responses: yes; no; refused; don't know).

Sociodemographic variables. We examined the following socio-demographic variables and their respective categories (in parentheses) in relation to e-cigarette use: age in years (18–44 – "younger adults"; 45–64 – "middle-aged adults"; ≥65 – "older adults"); gender (female; male); race/ethnicity (non-Hispanic whites; non-Hispanic blacks; Hispanics; Others); marital status (married or living with partner; divorced, separated, or widowed; never married); and U.S. Census region (Northeast; Midwest; South; West).

Time since initial cancer diagnosis. We calculated the time since cancer diagnosis by subtracting each participant's self-reported age at the time of first cancer diagnosis from their self-reported age at the time of the interview survey. The time since cancer diagnosis was then analyzed as a categorical variable with three groups: less than 2 years; 2–5 years; 5 years or more.

Alcohol use. We examined respondents' alcohol use in the following categories: lifetime abstainer (less than 12 alcohol drinks in lifetime); former drinker (12 or more alcohol drinks in lifetime but none in the past year); current light/moderate drinker (12 or more alcohol drinks in lifetime with up to 14 drinks per week for males or 7 drinks per week for females in the past year); and current heavy drinker (12 or more alcohol drinks in lifetime with more than 14 drinks per week for males or more than 7 drinks per week for females in the past year).

Statistical analysis

The prevalence of e-cigarette use was estimated for all those with smoking-related cancers combined as well as two larger subgroups who were survivors of lung cancer, and head and neck cancers. Prevalence of e-cigarette use was also estimated for subgroups defined: by age, gender, race/ethnicity, marital status, smoking history, quit attempt in past year, and time since initial cancer diagnosis.

For analytic purposes, "refused" or "don't know" responses to the survey questions were counted as missing.

We utilized chi-square tests to examine bivariate associations between current e-cigarette use and age, gender, race/ethnicity, marital status, smoking history, quit attempt in past year, time since initial cancer diagnosis, and alcohol use. A statistical significance level of 0.05 was utilized in the bivariate analyses for variable selection into the multivariate model.

Multinomial logistic regression modeling was utilized in examining the independent association between e-cigarette use and cigarette smoking, among all respondents with a history of smoking-related cancer, while simultaneously adjusted for known and measured confounders that were significantly associated with e-cigarette use on bivariate analyses.

Finally, we ran a multivariate logistic regression model that examined the independent association of e-cigarette use with cigarette smoking in the subset of respondents who had a lifetime history of a smoking-related cancer as well as a history of cigarette smoking history.

A statistical significance level of 0.05 was utilized in the multivariate analysis.

Survey weights correcting for the sample design and nonresponse were applied in obtaining the population-based prevalence rates, relative risk ratios (RRR), ORs, and their respective 95% confidence intervals (CI). All analyses were performed with Stata 14.2 (StataCorp).

The NCHS Ethics Review Board reviewed and approved the protocol for collection and public reporting of the NHIS data.

Results

There were 3,162 adult respondents with a history of smoking-related cancer diagnoses in the study sample (Table 1; Fig. 1). More than half (57%) of the respondents in the study sample were older adults, aged at least 65 years, and females (58%; Table 1). Most of the study respondents were non-Hispanic whites (80%), and about two-thirds (68%) were long-term survivors (≥ 5 years) of their initial diagnosed cancer (Table 1). Twenty percent ($n = 640$) were current smokers of which the majority (65%) smoked less than one pack per day, and slightly more than half had attempted quitting smoking within the prior year (Table 1). The majority of respondents reported having only one lifetime cancer diagnoses with the more prevalent diagnoses being: cervical cancer, 645 (20.40%); colorectal cancer, 643 (20.34%); lung cancer, 275 (8.70%); kidney cancer, 206 (6.51%); and head and neck cancer, 152 (4.81%; Supplementary Table S1).

The weighted prevalence rates of current e-cigarette use among adults with a history of smoking-related cancer were 3.18% (95% CI, 2.40%–3.96%; Table 2). Current e-cigarette use was associated with age ($P < 0.001$) with lower prevalence seen with older age; the prevalence of e-cigarette use among young adults 18–44 years was 6.28% (95% CI, 3.17%–9.39%) while older adults, aged 65 years and above, had a prevalence of 1.05% (95% CI, 0.53%–1.57%; Table 2). Current e-cigarette use was also associated with gender ($P = 0.047$) with a higher prevalence in females at 3.87% (95% CI, 2.74–4.99) relative to males in whom the prevalence was 2.30% (95% CI, 1.29%–3.31%; Table 2). Current e-cigarette use and alcohol use were associated with current heavy drinkers having a higher prevalence of e-cigarette use at 6.44% (95% CI, 1.59%–11.30%) relative to light/moderate drinkers at 3.64%

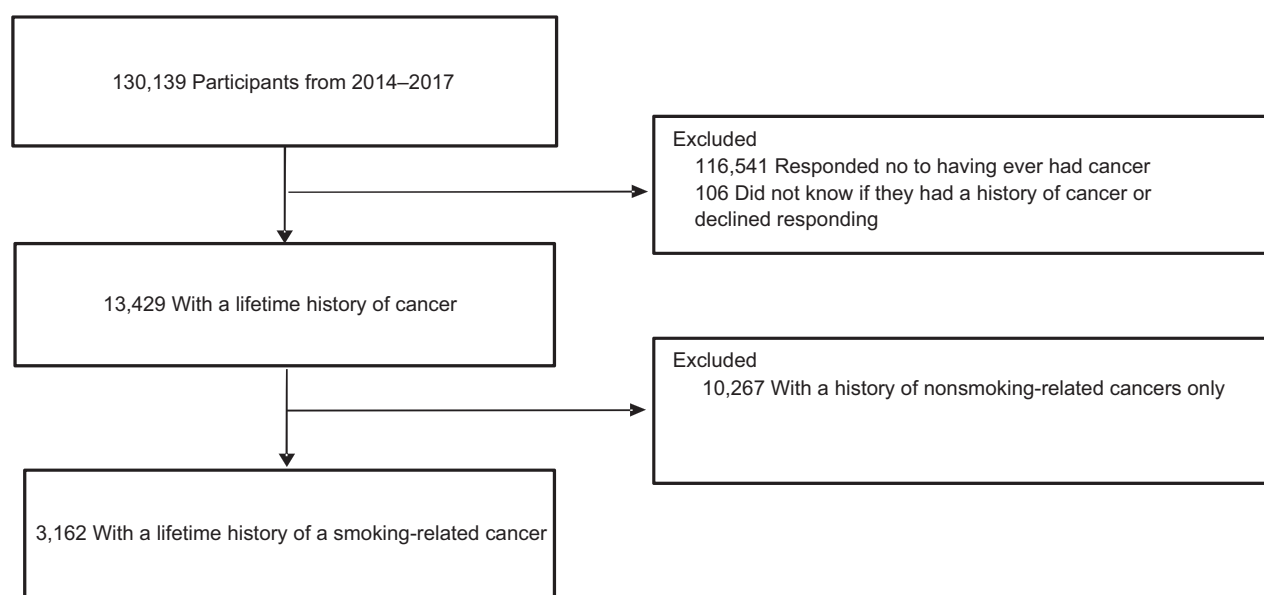
Table 1. Unweighted characteristics of adult patients and survivors of smoking-related cancers^a in the United States: National Health Interview Survey 2014–2017

Variable	N (%)
Age	
18–44 years	395 (12.49)
45–64 years	980 (30.99)
≥ 65 years	1,787 (56.51)
Gender	
Male	1,319 (41.71)
Female	1,843 (58.29)
Race/ethnicity	
Non-Hispanic White	2,525 (79.85)
Non-Hispanic Black	287 (9.08)
Hispanic	226 (7.15)
Others	124 (3.92)
Marital status	
Married/living with partner	1,506 (47.63)
Widowed/divorced/separated	1,357 (42.92)
Never married	293 (9.27)
Missing	6 (0.19)
Region ^b	
Northeast	548 (17.33)
Midwest	743 (23.5)
South	1,132 (35.8)
West	739 (23.37)
Survey year	
2014	818 (25.87)
2015	785 (24.83)
2016	861 (27.23)
2017	698 (22.07)
Time since cancer diagnosis	
Less than 2 years	454 (14.36)
2 years to less than 5 years	519 (16.41)
5 years or more	2,170 (68.63)
Missing	19 (0.6)
Alcohol use	
Lifetime abstainer	531 (16.79)
Former drinker	845 (26.72)
Current light/moderate drinker	1,575 (49.81)
Current heavy drinker	163 (5.15)
Missing	48 (1.52)
Smoking status	
Never smoker	1,152 (36.43)
Former smoker	1,353 (42.79)
Current smoker	640 (20.24)
Missing	17 (0.54)
Cigarette quantity ^c	
<1 pack per day	422 (65.94)
≥ 1 pack or more per day	208 (32.5)
Missing	10 (1.56)
One or more quit attempts in prior year ^c	
No	303 (47.34)
Yes	335 (52.34)
Missing	2 (0.31)
E-cigarette use	
Never user	2,648 (83.74)
Former user	341 (10.78)
Current user	116 (3.67)
Missing	57 (1.8)
Total	3,162 (100)

^aSmoking-related cancers defined as cancers of the bladder, cervix, colon, esophagus, kidney, larynx (windpipe), liver, lung, mouth/tongue/lip, pancreas, rectum, stomach, and throat (pharynx).

^bRegions as defined by the U.S. Census Bureau.

^cSubpopulation defined by cancer patients and survivors who were current smokers at the time of the interview.

**Figure 1.**

Selection schema for survivors of smoking-related cancers in the United States: National Health Interview Survey (NHIS) 2014–2017.

(95% CI, 2.46%–4.81%), and lifetime abstainers at 1.28% (95% CI, 0.31%–2.25%; Table 2).

Among those with a self-report of only one lifetime diagnosis of a smoking-related cancer, the prevalence of e-cigarette use was highest among patients and survivors of the following cancers: cervical cancer, 5.25% (95% CI, 3.19%–7.31%); lung cancer, 4.65% (95% CI, 1.49%–7.97%); pancreatic cancer, 4.12% (95% CI, 0.00%–12.91%); bladder cancer, 3.77% (95% CI, 0.86%–6.67%), and head and neck cancer, 2.49% (95% CI, 0.00%–5.11%; Supplementary Table S2).

Cigarette smoking was similarly associated with age, gender, region, and alcohol use (Supplementary Table S3). Other variables associated with cigarette smoking but not with e-cigarette use were race/ethnicity and marital status; these were not therefore selected into the multivariable model.

Current e-cigarette use was strongly associated with current cigarette smoking status ($P < 0.0001$), with 11.63% (95% CI, 8.28%–14.98%) of current smokers reporting current use of e-cigarettes compared with 2.18% (95% CI, 1.17%–3.19%) of former smokers, and 0.24% (95% CI, 0.00%–0.61%) of never smokers (Table 2). Current e-cigarette use was not significantly associated with cancer site (head/neck and lung cancers versus other smoking-related cancers), nor was it associated with other variables such as race/ethnicity, marital status, U.S. Census region, or time since initial cancer diagnosis (Table 2).

Among respondents who were current smokers, current e-cigarette use was neither associated with the number of cigarettes smoked daily nor with a smoking quit attempt in the prior year (Table 2).

On multivariate analysis that simultaneously controlled for the confounding effects of age, gender, region, and alcohol use, current e-cigarette users were 83 times as likely as those who had never used e-cigarettes to be current cigarette smokers (RRR, 82.89; 95% CI, 16.54–415.37; Table 3). Current e-cigarette users were about 10 times as likely as never users to be former cigarette smokers (RRR, 9.84; 95% CI, 1.94–49.87; Table 3).

A past history of e-cigarette use was strongly associated with current cigarette smoking (RRR, 59.95; 95% CI, 28.80–124.78; Table 3); with an association also seen between past e-cigarette use and being a former cigarette smoker (RRR, 4.75; 95% CI, 2.24–10.08; Table 3).

In the subpopulation of respondents who had a lifetime history of cigarette smoking as well as a smoking-related cancer, current users of e-cigarettes were 90% less likely to be former smokers relative to the odds of being a current smoker (OR, 0.10; 95% CI, 0.05–0.18; Table 4). Similarly, former use of e-cigarettes was associated with 92% lower odds of being a former smoker (OR, 0.08; 95% CI, 0.06–0.11; Table 4).

Discussion

Our analysis of cross-sectional data from a representative national survey shows that 3.18% of all adult patients and survivors of smoking-related cancers in the United States from 2014–2017 were current e-cigarette users. We found that current e-cigarette use among survivors of smoking-related cancers was associated with current and former cigarette smoking but not with increased smoking quit attempts in the prior year. Similarly, among those with a lifetime history of cigarette smoking, we found that current and past e-cigarette use was associated with a lower likelihood of former smoking, and conversely with a higher likelihood of current cigarette smoking. To the best of our knowledge, this analysis presents the first published national data regarding the association of e-cigarette use with cigarette smoking and with smoking quit attempts among patients and survivors of smoking-related cancers in the United States.

Our study estimate of the prevalence of e-cigarette use among adult survivors of smoking-related cancers in the United States from 2014–2017 [3.18% (95% CI, 2.40%–3.96%)] is similar to the CDC estimates of 3.5% (95% CI, 3.2%–3.6%) and 2.8% (95% CI, 2.5%–3.1%) for the general U.S. adult population in 2015 and 2017, respectively (12, 13). Our study estimate was also close to

Table 2. Weighted prevalence of e-cigarette use among adult patients and survivors of smoking-related cancers^a in the United States: National Health Interview Survey 2014–2017

Variable	%	95% CI	P ^b
Age			<0.001
18–44 years	6.28	3.17–9.39	
45–64 years	5.08	3.46–6.70	
≥65 years	1.05	0.53–1.57	
Gender			0.047
Male	2.30	1.29–3.31	
Female	3.87	2.74–4.99	
Race/ethnicity			0.241
Non-Hispanic White	3.50	2.58–4.43	
Non-Hispanic Black	1.35	0.22–2.48	
Hispanic	2.34	0.05–4.63	
Other	2.11	0.00 ^c –5.03	
Marital status			0.533
Married/living with partner	2.87	1.84–3.90	
Widowed/divorced/separated	3.75	2.44–5.06	
Never married	3.49	0.95–6.04	
Region ^d			0.237
Northeast	2.34	0.81–3.87	
Midwest	3.86	2.25–5.47	
South	3.74	2.25–5.22	
West	2.09	0.91–3.26	
Survey year			0.697
2014	3.77	2.16–5.37	
2015	2.48	1.04–3.92	
2016	3.01	1.43–4.59	
2017	3.43	1.95–4.92	
Time since cancer diagnosis			0.849
Less than 2 years	3.09	0.91–5.26	
2 years to less than 5 years	2.63	0.80–4.45	
5 years or more	3.24	2.35–4.13	
Alcohol use			0.027
Lifetime abstainer	1.28	0.31–2.25	
Former drinker	2.85	1.47–4.23	
Current light/moderate drinker	3.64	2.46–4.81	
Current heavy drinker	6.44	1.59–11.30	
Smoking status			<0.001
Never smoker	0.24	0.00 ^c –0.61	
Former smoker	2.18	1.17–3.19	
Current smoker	11.63	8.28–14.98	
Cigarette quantity ^e			0.841
<1 pack per day	11.35	7.27–15.43	
≥1 pack or more per day	12.06	6.25–17.87	
One or more quit attempts in prior year ^e			0.946
No	11.34	6.43–16.25	
Yes	11.57	7.11–16.04	
Overall study population	3.18	2.40–3.96	

^aSmoking-related cancers defined as cancers of the bladder, cervix, colon, esophagus, kidney, larynx (windpipe), liver, lung, mouth/tongue/lip, pancreas, rectum, stomach, and throat (pharynx).

^bP value for χ^2 tests of homogeneity between e-cigarette exposure and potential predictor variable.

^cLower bound of calculated confidence interval less than 0%.

^dRegions as defined by the U.S. Census Bureau.

^eSubpopulation defined by cancer patients and survivors who were current smokers at the time of the interview.

the estimated national prevalence of current e-cigarette use of 2.8% among all cancer survivors from analysis of the 2014 NHIS (14).

Our study results align with observational findings from a prior single-site cross-sectional study, by McQueen and colleagues among patients with head and neck cancer and survivors who were smokers, which found an e-cigarette prevalence of 21.7%, and that e-cigarette use may be negatively associated with suc-

cessful smoking cessation outcomes (10). The patient samples in that study and ours were similar with regards to patients having a history of smoking-related cancers; and both studies were cross-sectional in design. However, in the study by McQueen and colleagues, a convenience sample of patients at a surgical subspecialty office was recruited, and study enrolment was limited to patients with a history of tobacco use (10).

On the other hand, a single-institution observational study by Borderud and colleagues among patients with newly diagnosed cancer who were smokers referred to a hospital-based tobacco treatment program found a higher prevalence of e-cigarettes use and that current e-cigarette use may be associated with more frequent and recent quit attempts than nonusers (8); however, there was no association seen between e-cigarette use and smoking quit rates in that study (8). Similarly, Kalkhoran and colleagues found a higher prevalence of e-cigarette use among current cigarettes smokers with a recent cancer diagnosis participating in a multisite clinical trial but associations between e-cigarette use and smoking quit attempts and/or smoking cessation were not examined in that study (9).

The reasons for the disparate findings regarding the prevalence of current e-cigarette use as well as the association of e-cigarette use with smoking quit attempts in the studies by Borderud and colleagues and Kalkhoran and colleagues and our study are not quite clear (8, 9), but it is plausible that they may be partly explained by the differences in the study populations—patients in those studies were cessation treatment seeking smokers newly diagnosed with smoking-related and nonsmoking-related cancers.

The primary reason given for e-cigarette use among patients with newly diagnosed cancer has been to help with smoking cessation (9, 15), similar to findings from a cohort study in the general population in the Netherlands (16). We observe that although e-cigarette use was associated with former smoking, it was more strongly associated with current smoking. In the subgroup of smoking-related cancer survivors with a history of smoking, both current and former e-cigarette users were more likely to be current smokers rather than being former smokers. However, the cross-sectional nature of our study precludes making inferences regarding causality or directionality in the association between e-cigarette use and former smoking or smoking cessation. Taken together, our analyses and findings from other published observational studies in patients with cancer and survivors do not provide evidence for the effectiveness of e-cigarettes as an aid for smoking cessation among patients and survivors with a history of smoking-related cancers, who self-report current smoking, at any stage of their disease course or treatment.

Pertinent issues regarding the discussion of the use of e-cigarettes between patients and survivors of smoking-related cancers and their care providers relate to both the absence of regulation of e-cigarettes by agencies such as the FDA, and the absence of clinical practice guidelines recommending e-cigarette use as smoking cessation aides. Therefore, in discussing the use of e-cigarettes as smoking cessation aides with patients with cancer, oncology care providers may serve their patients well by pointing out these caveats and recommending evidence-based, safe, and effective pharmacologic and behavioral smoking cessation methods (17).

Our study did not examine the association of e-cigarette use with smoking cessation outcomes when combined with other

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Table 3. Weighted multinomial logistic regression^a examining the association between e-cigarette use and cigarette smoking among adult survivors of smoking-related cancers^b in the United States: National Health Interview Survey 2014–2017

Association between e-cigarette use and former smoking (outcome reference category: never smokers)			
Variable	Crude RRR (95% CI)	Adjusted RRR (95% CI)	P value for adjusted RRR
E-cigarette use			
Never user	Reference	Reference	Reference
Former user	4.75 (2.24–10.08)	6.41 (3.02–13.57)	<0.001
Current user	9.84 (1.94–49.87)	14.88 (2.73–71.05)	0.002
Age			
18–44 years	Reference	Reference	Reference
45–64 years	2.84 (1.50–3.47)	2.18 (1.39–3.42)	0.001
≥65 years	4.05 (2.72–6.03)	4.51 (2.94–6.92)	<0.001
Gender			
Male	Reference	Reference	Reference
Female	0.42 (0.34–0.52)	0.53 (0.42–0.67)	<0.001
Region^c			
West	Reference	Reference	Reference
South	1.19 (0.88–1.60)	1.31 (0.96–1.77)	0.092
Midwest	1.36 (1.00–1.85)	1.43 (1.03–1.98)	0.031
Northeast	1.34 (0.92–1.95)	1.33 (0.91–1.96)	0.138
Alcohol use			
Lifetime abstainer	Reference	Reference	Reference
Former drinker	4.04 (2.85–5.73)	3.74 (2.60–5.37)	<0.001
Current light/moderate drinker	3.56 (2.69–4.72)	3.91 (2.91–5.25)	<0.001
Current heavy drinker	7.64 (3.88–15.05)	7.90 (3.85–16.24)	<0.001
Association between e-cigarette use and cigarette smoking (outcome reference category: never smokers)			
E-cigarette use			
Never user	Reference	Reference	Reference
Former user	59.95 (28.80–124.78)	54.48 (25.68–115.57)	<0.001
Current user	99.87 (20.35–490.01)	82.89 (16.54–415.37)	<0.001
Age			
18–44 years	Reference	Reference	Reference
45–64 years	0.85 (0.60–1.22)	1.10 (0.62–1.93)	0.746
≥65 years	0.34 (0.23–0.49)	0.74 (0.42–1.28)	0.276
Gender			
Male	Reference	Reference	Reference
Female	1.03 (0.78–1.36)	0.85 (0.62–1.18)	0.338
Region^c			
West	Reference	Reference	Reference
South	1.74 (1.20–2.52)	1.93 (1.18–3.18)	0.009
Midwest	1.90 (1.26–2.88)	1.95 (1.17–3.24)	0.010
Northeast	1.34 (0.83–2.17)	1.77 (0.97–3.22)	0.061
Alcohol use			
Lifetime abstainer	Reference	Reference	Reference
Former drinker	4.91 (2.95–8.16)	4.39 (2.36–8.17)	<0.001
Current light/moderate drinker	3.97 (2.52–6.26)	3.22 (1.81–5.73)	<0.001
Current heavy drinker	15.89 (7.31–34.55)	13.97 (5.96–32.78)	<0.001

^aOutcome variable: cigarette smoking (current smokers vs. never smokers; former smokers vs. never smokers). Covariates (in addition to e-cigarette use): age, gender, region, and alcohol use.

^bSmoking-related cancers defined as cancers of the bladder, cervix, colon, esophagus, kidney, larynx (windpipe), liver, lung, mouth/tongue/lip, pancreas, rectum, stomach, and throat (pharynx).

^cRegions as defined by the U.S. Census Bureau.

pharmacologic or nonpharmacologic smoking cessation strategies, and this represents an important direction for future research, particularly given the strong uptake of e-cigarette use among patients with cancer and survivors.

Limitations

Several limitations of our study should be noted. First, we were unable to examine associations between e-cigarette use and smoking cessation from this secondary data analysis due to the absence of temporal data that would have facilitated the determination of the relative timing of cancer diagnosis to e-cigarette

use among e-cigarette users, or the relative timing of e-cigarette uptake to smoking cessation among former smokers.

Second, the self-report of cancer has been reported to be associated with underreporting of cancer diagnoses. However, we are unaware of data suggesting that such possible underreporting of cancer diagnosis may bias self-reporting of e-cigarette use among cancer.

Third, our study's objective regarding the association between e-cigarette use and smoking quit attempts is based on the premise that e-cigarette users who were smokers at the time of e-cigarette uptake adopted e-cigarette use as an aide to smoking cessation. We were unable to assess the readiness and/or motivation of

Table 4. Weighted logistic regression^a examining the association between e-cigarette use and cigarette smoking among adult survivors of smoking-related cancers^b with history of smoking in the United States: National Health Interview Survey 2014–2017

Association between e-cigarette use and former smoking (outcome reference category: current smokers)			
Variable	Crude OR (95% CI)	Adjusted OR (95% CI)	P value for adjusted OR
E-cigarette use			
Never user	Reference	Reference	Reference
Former user	0.08 (0.06–0.11)	0.11 (0.08–0.17)	<0.001
Current user	0.10 (0.05–0.18)	0.16 (0.09–0.30)	<0.001
Age			
18–44 years	Reference	Reference	Reference
45–64 years	2.67 (1.75–4.07)	2.25 (1.30–3.88)	0.004
≥65 years	12.03 (7.92–18.27)	6.78 (3.96–11.62)	<0.001
Gender			
Male	Reference	Reference	Reference
Female	0.41 (0.31–0.53)	0.70 (0.51–0.95)	0.023
Region ^c			
West	Reference	Reference	Reference
South	0.68 (0.47–0.99)	0.69 (0.42–1.15)	0.153
Midwest	0.71 (0.48–1.05)	0.82 (0.49–1.38)	0.458
Northeast	1.00 (0.60–1.65)	0.83 (0.46–1.47)	0.510
Alcohol use			
Lifetime abstainer	Reference	Reference	Reference
Former drinker	0.82 (0.49–1.39)	0.72 (0.38–1.35)	0.301
Current light/moderate drinker	0.90 (0.56–1.44)	1.06 (0.60–1.88)	0.200
Current heavy drinker	0.48 (0.25–0.93)	0.51 (0.24–1.08)	0.079

^aOutcome variable: cigarette smoking (former smoker vs. current smokers). Covariates (in addition to e-cigarette use): age, gender, region, and history of alcohol use.

^bSmoking-related cancers defined as cancers of the bladder, cervix, colon, esophagus, kidney, larynx (windpipe), liver, lung, mouth/tongue/lip, pancreas, rectum, stomach, and throat (pharynx).

^cRegions as defined by the U.S. Census Bureau.

concurrent cigarette smokers and e-cigarette users to quit smoking at the time of e-cigarette uptake, as well as the reasons for e-cigarette uptake among patients in this study. However, as noted earlier, a prior study suggests that the overwhelming majority (92%) of currently smoking patients with cancer initiate e-cigarette use as a smoking cessation aid (9).

Fourth, all data including cancer history, smoking history, and e-cigarette use, were all obtained via self-report, which raises concern for possible underreporting of these variables and misclassification bias. Indeed, studies suggest that cancer survivors often underreport their cancer history in surveys (18–22). Similarly, patients with cancer and survivors may misreport their e-cigarette use and smoking status (23, 24). However, we have no reason to believe that underreporting of cancer diagnosis or current smoking status would significantly alter our study prevalence estimates given the similar rates of e-cigarette use in those with self-reported cancer history in our study relative to the general population (3, 12).

Finally, we cannot eliminate the possibility of residual confounding from our multivariable analyses though we examined and appropriately adjusted our analysis for confounders available from the survey data.

Conclusions

In conclusion, our study demonstrates that e-cigarette use among patients and survivors of smoking-related cancers was not associated with increased quit attempts in the prior year; and in the subgroup of patients and survivors with a history of cigarette smoking, current e-cigarette users were less likely to be former smokers than they were to be current smokers. Our study

does not suggest that e-cigarette use is associated with an increased likelihood of smoking quit attempts or successful smoking cessation, and it does not provide evidence for recommending e-cigarette use for smoking cessation among patients and survivors of smoking-related cancers. Future studies are needed to prospectively examine, in a randomized controlled trial, the effectiveness of e-cigarette use as a smoking cessation aide among patients with cancer and survivors.

Disclosure of Potential Conflicts of Interest

J.S. Ostroff reports receiving other commercial research support from CVS Foundation. No potential conflicts of interest were disclosed by the other authors.

Authors' Contributions

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Development of methodology: O. Akinboro, O. Ola, J.S. Ostroff
Acquisition of data (provided animals, acquired and managed patients, provided facilities, etc.): O. Akinboro, O. Balasire
Analysis and interpretation of data (e.g., statistical analysis, biostatistics, computational analysis): O. Akinboro, O. Ola
Writing, review, and/or revision of the manuscript: O. Akinboro, S.M. Nwabudike, R. Elias, O. Balasire, O. Ola, J.S. Ostroff
Administrative, technical, or material support (i.e., reporting or organizing data, constructing databases): O. Akinboro

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