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Documentation of e-cigarette use and associations with smoking from 2012 to 2015 in an integrated healthcare delivery system

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ABSTRACT

It is unclear whether use of electronic nicotine delivery systems (ENDS) precedes cigarette smoking initiation, relapse, and/or quitting. Healthcare systems with electronic health records (EHRs) provide unique data to examine ENDS use and changes in smoking.

We examined the incidence of ENDS use (2012–2015) based on clinician documentation and tested whether EHR documented ENDS use is associated with twelve-month changes in patient smoking status using a matched retrospective cohort design. The sample was Kaiser Permanente Northern California (KPNC) patients aged ≥12 with documented ENDS use (N = 7926); 57% were current smokers, 35% former smokers, and 8% never-smokers. ENDS documentation incidence peaked in 2014 for current and former smokers and in 2015 for never-smokers. We matched patients with documented ENDS use to KPNC patients without documented ENDS use (N = 7926) on age, sex, race/ethnicity, and smoking status.

Documented ENDS use predicted the likelihood of smoking in the following year. Among current smokers, ENDS use was associated with greater odds of quitting smoking (OR = 1.17, 95%CI = 1.05–1.31). Among former smokers, ENDS use was associated with greater odds of smoking relapse (OR = 1.53, 95%CI = 1.22–1.92). Among never-smokers, ENDS use was associated with greater odds of initiating smoking (OR = 7.41, 95%CI = 3.14–17.5). The overall number of current smokers at 12 months was slightly higher among patients with (N = 3931) versus without (N = 3850) documented ENDS use.

Results support both potential harm reduction of ENDS use (quitting combustibles among current smokers) and potential for harm (relapse to combustibles among former smokers, initiation for never-smokers).

1. Introduction

Cigarette smoking, including exposure to secondhand smoke, is linked to > 520,000 deaths in the US each year, and smoking-related illnesses result in nearly $170 billion in direct medical costs and $156 billion attributable to lost work productivity annually (Xu et al., 2015). Alternatives to smoking, such as electronic nicotine delivery systems (ENDS), which include electronic cigarettes, have become increasingly popular in recent years (McMillen et al., 2015; Pearson et al., 2012; Regan et al., 2013; King et al., 2015). Regulated as a tobacco product by the U.S. Food and Drug Administration (FDA) since May 2016 (*Fed. Regist.*, 2016), data on the potential of ENDS for harm enhancement and harm reduction are limited. Given the substantial harms of combustible cigarettes, ENDS are thought to be safer nicotine delivery products. Similarly, there is some evidence of health benefits among smokers who fully switch to vaping ENDS (Farsalinos and Polosa, 2014; McRobbie et al., 2014; Farsalinos et al., 2016; Nolan et al., 2016). Further, ENDS may help some smokers cut down on or quit cigarette smoking, although dual use remains common (Hartmann-Boyce et al., 2016). There is concern, however, that these products may serve as a gateway to smoking initiation (Primack et al., 2015; Leventhal et al., 2015; Chatterjee et al., 2016) and encourage relapse among those who have recently quit smoking (U.S. Department of Health and Human Services, 2016; Bhatnagar et al., 2014). Simulation-based models indicate that the potential net effects of ENDS use on population health depend on a number of factors, including the impact of ENDS on cigarette smoking

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initiation and cessation, ENDS toxicity, and patterns of use (Kalkhoran and Glantz, 2015; Levy et al., 2017a).

As patients increasingly turn to their healthcare providers for information about ENDS (Nickels et al., 2017; Steinberg et al., 2015; El-Shahawy et al., 2016; Kandra et al., 2014), research is critically needed to increase the surveillance of their use in healthcare settings (Young-Wolff et al., 2017). To fill this gap in the literature, we analyzed data from a large, integrated healthcare delivery system to describe the incidence of patients' ENDS use based on clinician documentation in the EHR from 2012 to 2015 and to test whether ENDS use was associated with changes in patients' smoking status (i.e., starting, quitting, relapsing) in the subsequent year using a matched retrospective cohort design.

2. Methods

2.1. Setting

Kaiser Permanente Northern California (KPNC) is a nonprofit, multispecialty healthcare delivery system providing comprehensive health services to > 4 million members (Kaiser Permanente, 2011) and covering ~40% of the region's commercially insured population (Report, 2013). KPNC provides integrated medical and behavioral health treatment and is a recognized leader in establishing tobacco treatment quality-of-care standards (Goldstein et al., 2005). Members are racially and socio-economically diverse, and highly representative of the population in the geographic catchment area (Selby et al., 2005). KPNC institutional review board approval was obtained for this study.

2.2. Study participants

Our study population comprised 3,680,549 patients aged ≥12 with KPNC membership and ≥1 clinical contact between January 1, 2012 and December 31, 2015. Within this population, $N = 8256$ patients had ≥1 valid instance of documented ENDS use in the EHR during this timeframe.

For the matched-case analyses examining changes in smoking status over the subsequent year, we matched each patient with documented ENDS use to a patient without documented ENDS use on age, sex, race/ethnicity, and smoking status in the same month and year as the first documented ENDS use. For matched patients without documented ENDS use who had multiple recorded smoking statuses at different times during the study period, we randomly sampled one smoking status before employing the matching algorithm to ensure that each patient was matched only once. Of documented ENDS users, 646 of the 664 never-smokers (97%), 2752 of the 2857 former smokers (96%), and 4528 of the 4735 current smokers (96%) were successfully matched to patients without documented ENDS use, resulting in samples of $n = 7926$ documented ENDS users and $n = 7926$ matched patients without documented ENDS use.

2.3. Measures

2.3.1. Identification of documented ENDS use

We used natural language processing techniques to identify instances of ENDS use, based on clinicians' documentation in the tobacco-use free text field within the social history section of the Epic EHR. We created a set of specific "shorthand" text strings (i.e., a series of characters one would expect to find within the keywords, such as "e-cig," "electronic," or "vape") and used the SAS INDEX function (substring matches) to capture suspected variations of ENDS keywords in the tobacco comments. When we found new, potential flags, we manually reviewed the full comments for inclusion, alternative candidate strings, and exclusionary criteria (Appendix 1). We included only keywords that referenced ENDS (e.g., electronic cigarette but not electronic signature). We included the first (earliest) documented ENDS reference for each patient to estimate the number of *new* documented ENDS users in each year (2012–2015).

2.3.2. Smoking status

KPNC has several systems in place to ensure that smoking status is routinely asked about and documented, including an EHR prompt that triggers staff to ask about patients' smoking status and management oversite of staff documentation of patient smoking. Overall, tobacco screening rates are about 90%, with the highest rates in primary care. We obtained patient-reported smoking status (i.e., current, former, or never-smoker) from the EHR (Goldstein et al., 2005). Prior studies support the validity of EHR-based smoking status data (McGinnis et al., 2011; McVeigh et al., 2016; Marston et al., 2014). KPNC clinicians began consistently documenting "former smoking" status in 2012, and our study included years 2012–2015. We included the smoking status from the same encounter as the earliest ENDS documentation. If no smoking status was associated with that encounter (19%), we included the last recorded smoking status preceding ENDS documentation.

We categorized current smokers as "quitting" if they had ≥1 "former smoker" status during the year following ENDS documentation. Quitting did not have to be sustained in future records to be coded as "quitting." We categorized former smokers and never-smokers as starting smoking if they had ≥1 "current smoker" status during the year following ENDS documentation.

2.3.3. Demographic variables

Data on patient sex, race/ethnicity, age, and neighborhood median household income were from the EHR. Neighborhood median household income was geocoded from census data using patients' addresses and was dichotomized as 1 (≤median household salary) or 0 (> median household salary).

2.3.4. Comorbidity diagnoses

We identified the most common psychiatric disorders (depressive disorders, anxiety disorders, attention deficit hyperactivity disorders, bipolar spectrum disorders, substance use disorders and psychotic disorders) in our sample based on current ICD-9 and ICD-10 diagnoses recorded in the EHR during the year after ENDS use documentation.

2.3.5. Tobacco cessation medications

Use of tobacco cessation medication was determined by dispensation of any FDA-approved tobacco cessation medication (i.e., nicotine replacement therapy (NRT) gum, lozenge, inhaler, patch, nasal spray, or varenicline) from a KPNC pharmacy in the year following earliest recorded ENDS use, or the date of the matched recorded smoking status. Because bupropion is commonly prescribed to treat depressive disorders and not solely as a smoking cessation aid, it was not included in analyses. Data were extracted from the KPNC Pharmacy Information Management System database, which contains all data related to prescriptions dispensed at a KPNC pharmacy.

2.4. Analysis

Analyses were conducted in 2016 and 2017 using SAS© software, version 9.3. We first calculated the annual incidence rate of ENDS-use documentation in the EHR, defined as the number of newly documented ENDS users per 1000 KPNC patients with a documented clinical encounter in a given year, from 2012 to 2015. We plotted annual incidence rates by smoking status to visualize the relative increases in documentation among current smokers, former smokers, and never-smokers.

We calculated the percentage of ENDS users and matched non-users of each smoking status with a 12-month change in smoking status (i.e., quit smoking, initated smoking, or relapsed) and used chi-square tests to assess statistical significance. We then estimated the association between ENDS-use documentation and a 12-month change in smoking