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Short communication

Use and perceptions of electronic nicotine delivery systems among patients attending lung cancer screening who smoke

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ABSTRACT

Given accumulating evidence that electronic nicotine delivery systems (ENDS) may be a harm-reduction alternative to combustible tobacco products, it is important to understand the real-world implications of these devices in the populations that may benefit from them the most. We surveyed the use, perceptions of, and interest in using ENDS among patients attending their initial low-dose CT scan (LDCT) for lung cancer screening (LCS) who reported current smoking, a cohort of older individuals at high-risk for lung cancer and other smoking-related illnesses due to their heavy smoking history (30 or more pack years). Participants (N = 107) completed the survey in clinic immediately before their shared decision-making visit for lung cancer screening on the day of their LDCT. Approximately a quarter of participants reported ever use of ENDS in the past; nearly a third expressed a willingness to try switching to them in the future. Prior ENDS use was significantly associated with willingness to try switching to ENDS in the future. The most common reasons to consider switching included smoking cessation and harm reduction. Only about a third were aware that ENDS are not approved by the FDA for smoking cessation; knowledge significantly varied by demographic and clinical characteristics. These findings have important implications for ENDS public health campaigns and tobacco harm reduction strategies for older individuals who smoke.

1. Introduction

Cigarette smoking is the leading preventable cause of death in the United States, contributing to more than 480,000 deaths annually (U.S. Department of Health and Human Services, 2020). It is also the primary risk factor for lung cancer and lung cancer survival rates remain poor among those who smoke (U.S. Department of Health and Human Services, 2020). Smoking cessation has substantial general health benefits and specific benefits for lung cancer risk and prognosis (U.S. Department of Health and Human Services, 2020). Despite these benefits, older people who smoke and are at heightened risk for lung cancer are less likely to be interested in smoking cessation and to achieve abstinence than their younger counterparts (Chen and Wu, 2015). In light of these challenges, tobacco harm reduction alternatives are critically needed for older individuals who are unwilling or unable to quit. Electronic nicotine delivery systems (ENDS), which include e-cigarettes, vaping devices, or vape pens, may provide an option (U.S. Department of Health and Human Services, 2020). ENDS contain markedly lower levels of toxic and potentially harmful substances, but they are not harm-free (National Academies of Sciences, Engineering, and Medicine, 2018; U.S. Department of Health and Human Services, 2020). ENDS products are highly addictive and appealing to users (e.g., JUUL®) (Vallone et al., 2020). There is accumulating evidence of their potential to reduce exposure to many of the toxicants and carcinogens produced by tobacco combustion (U.S. Department of Health and Human Services, 2020; Hatsukami, 2020). Furthermore, ENDS may help some adults who smoke switch from combustible cigarettes (Hajek et al., 2019; U.S. Department of Health and Human Services, 2020; Walker et al., 2020). Nevertheless, the extent to which these findings apply to those who are older and at increased risk for serious smoking-related health

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consequences is not clear. ENDS harm reduction studies have not typically focused on this subgroup.

ENDS use prevalence among individuals with medical conditions (e.g., cancer, chronic obstructive pulmonary disease) who smoke may be increasing and may be greater than that among those without any comorbidities (Kalkhoran et al., 2018; Kruse et al., 2017). Moreover, this association may be stronger among younger individuals who smoke (i.e., <50 years old) (Sanford et al., 2019). Cessation/harm reduction is often the primary reason for using ENDS among these subgroups (Kalkhoran et al., 2018). The results of at least one study suggest that patients with cancer who use ENDS may perceive less risks from these products compared to smoking and greater smoking cessation benefit compared to nicotine replacement therapy (Correa et al., 2018). Nevertheless, data on the effectiveness of ENDS for cessation/smoking reduction are mixed (U.S. Department of Health and Human Services, 2020). Given these equivocal findings and the limited research on older populations, more research on ENDS use, reasons for use, and perceptions among older people who smoke at increased risk for lung cancer and other smoking-related illnesses is warranted.

To add to this emerging evidence base, we investigated the use, perceptions of, and interest in using ENDS among individuals attending their initial low-dose CT scan (LDCT) for lung cancer screening (LCS) who reported smoking. LCS eligibility criteria are intended to capture those who are at high risk for developing lung cancer and by default, other major health risks (e.g., cardiovascular and pulmonary diseases) (Fucito et al., 2016). As an older cohort, they may have unique challenges that impair their smoking cessation motivation and success (U.S. Department of Health and Human Services, 2020; Chen and Wu, 2015). One study of LCS patients showed decreased motivation to quit smoking among some patients, possibly due to misperceptions of minimal harm from tobacco use if screening results are negative (Zeliadt et al., 2015). However, the impact of LCS on smoking remains an open question. A series of ongoing smoking cessation trials in the context of LCS will inform how LCS may affect cessation motivation (Joseph et al., 2018). Nevertheless, among LCS patients not interested in smoking cessation, a tobacco harm reduction option may be both appealing and beneficial. Lucchiari and colleages recently conducted a randomized controlled trial of e-cigarettes in LCS patients (N = 210) (Lucchiari et al., 2020). All participants received smoking cessation counseling and were randomized to receive (1) a nicotine e-cigarette, (2) a nicotine-free e-cigarette, or (3) no e-cigarette. Participants in the e-cigarette group had the greatest reductions in smoking and lowest levels of exhaled carbon monoxide and nicotine dependence as compared with the other two groups. Besides this recent trial, little is known about the use, perceptions of, and willingness to try ENDS among LCS patients. Since LCS benefits are optimized by smoking cessation (Fucito et al., 2016); it is imperative to understand whether ENDS may be an acceptable and feasible strategy to move this high-risk group of individuals who smoke along the continuum of change for their tobacco use behaviors.

2. Methods

2.1. Procedures

Between January and November 2019, 150 individuals who reported current smoking (i.e., ≥1 combustible cigarette(s) within the past 30 days) attending an initial LCS appointment at a cancer hospital and an affiliated ambulatory care center were eligible to participate in a brief, anonymous survey. Following informed consent procedures, 107 interested volunteers completed the survey in clinic (107/150 = 71% rate of completion). Participants were not compensated. The study protocol was reviewed and approved by the Institutional Review Board at the Yale School of Medicine prior to survey distribution and data collection.

2.2. Measures

The brief survey incorporated validated tobacco-related assessments, and assessed these domains: (1) demographics: (2) self-reported medical status (i.e., ever diagnosed by a healthcare provider with COPD, chronic bronchitis, emphysema, asthma, stroke, heart attack, cancer); (3) motivation to quit smoking in the next 30 days on a 10-point Likert-scale; (4) Heaviness of Smoking Index (HSI) (Heatherton et al., 1989), which measures number of cigarettes smoked per day, time to first cigarette, and yields a total nicotine dependence score (i.e., ≥5 indicative of high dependence); (5) number of prior quit attempts for ≥24 h (0–5 or more); (6) any quit attempt in the past year; (7) ever-use of various ENDS products (i.e., disposable/rechargeable "cig-a-like" devices, JUUL®/pod e-cigarettes, or hookahs/vape pens/mods) which were displayed to participants using pictures or nicotine replacement products (i.e., patch, gum, lozenge, spray, or inhaler).

Participants also indicated their future willingness to use ENDS or nicotine replacement therapy (NRT) for any of following reasons: (1) as a replacement when smoking is not permitted; (2) to reduce harm to themselves or others; (3) to reduce or quit smoking; (4) due to curiosity/intrigue about the product; or (5) because these products are more socially acceptable. Additionally, respondents were asked if they knew whether ENDS have been approved by the FDA for smoking cessation, response options: "yes", "no", "I don't know." The primary study focus was on ENDS but NRT questions were included to understand how participants' preferences for ENDS compared with those for evidence-based tobacco treatment options.

2.3. Data analysis

All analyses were run using SPSS (IBM, Version 26). For analysis purposes, some variables were coded as binary. Race/ethnicity (0 = non-Hispanic/white, 1 = non-white or Hispanic), medical status (0 = no medical conditions, 1 = 1+ medical conditions), and quit attempts in past year (0 = no, 1 = yes) were recoded as binary due to smaller sample sizes across categories. HSI scores were coded as binary in correspondence with the suggested cutoff scores for high nicotine dependence (0 = scores less than 5, 1 = scores 5 or more). We also dichotomized correct knowledge of FDA status (0 = no, 1 = yes); responses of "I don't know" or blank responses were recoded as "no." We used descriptive statistics to characterize the sample and evaluate ENDS-related variables (i.e., Fisher's Exact tests for categorical variables, t-tests for continuous variables). Percentages are reported out of the total number of patients surveyed (N = 107). Due to survey time constraints, some participants had missing or incomplete responses for: (1) ever use of NRT and ENDS (n = 4); (2) willingness to try any ENDS (n = 11); (3) ENDS FDA status (n = 12). For these analyses, we compared participants who positively or correctly endorsed an item relative to those who did not either by marking a response or leaving it blank.

3. Results

3.1. Demographic and smoking characteristics of patients attending LCS who report current smoking

Table 1 shows participant demographic and clinical characteristics. Most participants reported a history of successfully quitting smoking at least once in the past; around half reported a quit attempt in the past year. Half of the sample reported ever using NRT for smoking cessation. Participants expressed moderate motivation to quit in the next month.

3.2. Prior ENDS use and beliefs/knowledge about ENDS

As shown in Table 1, more than a quarter of the sample reported ever using ENDS in the past, with disposable/rechargeable cig-a-like e-cigarettes being the most commonly used device type among those assessed.

Table 1
Demographic and smoking characteristics of current patients attending lung cancer screening who smoke (N = 107).

Age, M (SD)	61.8 (4.82) years
Sex, % male (N)	59.8% (64)
Race, % white (N)	
White	67.3% (72)
Black	25.2% (27)
Missing	7.5% (8)
Ethnicity, % (N)	
Hispanic/Latino/Latina	9.3% (10)
Non-hispanic/non-Latino/non-Latina	87.9% (94)
Missing	2.8% (3)
1 or more medical comorbidities, % (N)	50.5% (54)
Pulmonary	42.1% (45)
Cardiovascular	14.0% (15)
Cancer	4.7% (5)
Cigarettes per day, M (SD)	13.3 (8.68)
Heaviness of Smoking Index, M (SD)	2.58 (1.41)
Motivation to quit, M (SD)	6.33 (3.43)
Quit smoking for ≥ 24 h, % (N)	63.6% (68)
Quit attempt in past year, % (N)	47.7% (51)
# of prior quit attempts, M (SD)	2.5 (2.09)
Ever use - NRT, % (N)	50.5% (54)
Ever use - any ENDS, % (N)[1]	28.0% (30)
Cig-a-like	20.1% (22)
Hookah/vape pen/mod	15.9% (17)
JUUL® e-cigarette	3.7% (4)
Willing to try switching to any ENDS, % (N)[2]	31.8% (34)
Cig-a-like	19.6% (21)
Hookah/vape pen/mod	16.8% (18)
JUUL® e-cigarette	15.0% (16)
Reasons to consider ENDS (N = 34 willing to try switching), % (N)	
Cut down/quit	64.7% (22)
Reduce health risks to self or others	61.8% (21)
No smoking area	55.9% (19)
Socially acceptable	47.1% (16)
Curiosity	35.3% (12)
Reasons to consider NRT (N = 34 willing to try switching), % (N)	
Cut down/quit	58.8% (20)
Reduce health risks to self or others	52.94% (18)
No smoking area	50.0% (17)
Socially acceptable	44.1% (15)
Curiosity	35.3% (12)
Correct knowledge of ENDS FDA status, % (N)	32.7% (35)

[1] Any use of ENDS – whether participant endorsed any of the 3 categories.
[2] Willing to try switching to any ENDS – whether participant endorsed any of the 3 categories.

Past ENDS use did not vary by participant demographic or clinical characteristics. Only a third of participants correctly knew that ENDS are *not* FDA-approved for smoking cessation. As seen in Table 2, men and white, non-Hispanic participants were more likely to know the correct FDA status of ENDS compared to women and non-white or Hispanic respondents. In addition, participants with higher nicotine dependence and lower motivation to quit were more knowledgeable about the FDA status of ENDS compared to their counterparts.

3.3. Willingness to switch to ENDS in the future

As shown in Table 1, nearly a third of participants expressed a willingness to try switching to ENDS products, with similar preferences among device types. Those who reported ever using ENDS were significantly more likely to express a willingness to try switching to ENDS in the future compared to their counterparts who had never used ENDS (*Fisher's Exact Test* = 0.001). No significant associations were found between participant characteristics and willingness to try switching to ENDS in the future.

Among the subsample of 34 participants who expressed an openness to switching to ENDS in the future, the most common reasons selected for using ENDS in the future included (see Table 1): smoking cessation/reduction and harm reduction, followed by use in places that do not allow smoking, social acceptability, and curiosity/intrigue. Among these 34 participants, similar patterns for reasons to try ENDS were observed for NRT as well. Willingness to try switching to ENDS for smoking cessation/reduction and willingness to use NRT for smoking cessation/reduction were significantly associated (*Fisher's Exact Test* = 0.04). Most participants who endorsed smoking cessation/reduction as reasons to use ENDS in the future also endorsed these reasons to use NRT (72.7%).

Table 2
Relation of demographic and clinical characteristics to correct knowledge about ENDS FDA status (N = 107).

Characteristics	Descriptives for significant differences	Test statistic and p value
Sex	Men: 42.2% (27/64) Women: 18.6% (8/43)	*Fisher's Exact Test* = 0.012*
Race/Ethnicity	white/non-Hispanic: 43.5% (30/69) non-white or Hispanic: 13.5% (5/37)	*Fisher's Exact Test* = 0.002*
Nicotine Dependence (HSI Score)	Correct knowledge: $M = 3.1$, $SD = 1.42$ Incorrect knowledge: $M = 2.3$, $SD = 1.34$	$t(96) = -2.63$, $p = 0.01$*
Tried to quit smoking in the past year		*Fisher's Exact Test* = 0.53
Motivation to quit smoking	Correct knowledge: $M = 5.3$, $SD = 3.48$ Incorrect knowledge: $M = 6.9$, $SD = 3.30$	$t(92) = 2.11$, $p = 0.04$*
Medical co-morbidities		*Fisher's Exact Test* = 0.84

4. Discussion

This is the first study to our knowledge on the use, perceptions of, and interest in ENDS among patients participating in annual lung cancer screening (LCS) who smoke. The results demonstrated that both prior experience with and interest in using ENDS is common in this population. Prevalence of ever ENDS use was lower than reported in prior studies of smokers in the general population (Delnevo et al., 2016; King et al., 2015) and older smokers (Kruse et al., 2017). Contrary to expectations, we did not show that ENDS use history was greater among smokers with one or more co-morbid medical conditions as reported by a previous large population survey (Kruse et al., 2017). This study, however, assessed a more narrow age range of smokers and did not measure reasons for prior ENDS use or the timing of ENDS use relative to the onset of any medical conditions.

Interest in using ENDS products in the future was significantly associated with prior ENDS use but unrelated to participants' demographic or clinical characteristics. The subset of participants who expressed interest in using ENDS in the future cited smoking cessation and/or tobacco-related harm reduction as primary reasons rather than because of restrictions on smoking and/or novelty. This subsample reported a similar willingness to use nicotine replacement therapy (NRT) in the future for these reasons. These results are consistent with prior surveys of adults showing that cessation and health were the most common reasons for ENDS use (Patel et al., 2016). This study expands upon this prior research by comparing interest in using ENDS and reasons for use with that for NRT. Our findings suggest that a number of LCS patients are motivated to change their smoking and are open to various strategies for this purpose. Importantly, not all LCS patients are interested in smoking cessation (Joseph et al., 2018). Yet, only one study has examined alternate tobacco products for this population (Lucchiari et al., 2020).

This study also documented a striking lack of knowledge about ENDS among LCS patients. Only a third of participants correctly knew that

ENDS are *not* FDA-approved for smoking cessation. While this proportion of *correct* knowledge is higher than previously documented (Berg et al., 2015); most participants were still unaware of the FDA's stance on ENDS or misperceived that ENDS were FDA-approved for smoking cessation. This lack of knowledge was greater among women, non-white/Hispanic participants and those with greater nicotine dependence/lower cessation motivation. Inaccurate perceptions/knowledge about ENDS among women and non-white individuals has been reported elsewhere (Berg et al., 2015; Harlow et al., 2019; King et al., 2015; Patel et al., 2016), but this is the first study to show this association in this subgroup of individuals seen for LCS and a relation between ENDS knowledge and smoking clinical characteristics. These subgroup trends may be due to a number of factors including differences in access to ENDS or information about these products as well as prior experience using ENDS or education level (Hartwell et al., 2017).

Several study limitations should be noted. The study utilized an opportunity sampling approach with patients who reported current smoking attending LCS at a large academic medical center in the northeastern U.S., thus limiting its generalizability. The smoking characersitics and/or willingness to try ENDS or NRT among participants who completed our survey may not be representative of the broader population of older individuals who attend LCS. We conducted the survey immediately prior to LCS and during the outbreak of e-cigarette, or vaping, product use-associated lung injury (EVALI) (U.S. Department of Health and Human Services, 2020), which may have biased participants' responses. Due to missing data, some estimates of ENDS use and perceptions may be underreported. In an effort to keep the survey brief, we did not assess socioeconomic status, some characteristics related to ENDs use such as flavors or risk perceptions, or reasons for not wanting to use ENDS. These are all content areas that should be explored in future ENDS surveys.

In summary, this study documented that ENDS use and interest in trying ENDS are common among LCS patients who report current smoking, principally for smoking cessation/harm reduction but many LCS patients remain uninformed about these products. Together, these results highlight the importance of discussing and offering tobacco treatment and harm reduction assistance to those undergoing LCS who smoke and addressing their misperceptions about these strategies.

CRediT authorship contribution statement

Lisa M. Fucito: Conceptualization, Methodology, Project administration, Supervision, Formal analysis, Writing - original draft, Writing - review & editing. **Krysten W. Bold:** Conceptualization, Methodology, Investigation, Supervision, Formal analysis, Writing - review & editing. **Stephen R. Baldassarri:** Writing - review & editing. **John P. LaVigne:** Investigation, Data curation, Formal analysis. **Bennie Ford:** Conceptualization, Methodology, Investigation. **Polly Sather:** Project administration, Supervision, Investigation. **Stephanie S. O'Malley:** Conceptualization, Methodology, Writing - review & editing. **Benjamin A. Toll:** Conceptualization, Methodology, Writing - review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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