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RESEARCH ARTICLE

# Association Between Electronic Cigarette Use and Myocardial Infarction

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**Introduction:** Electronic cigarettes (e-cigarettes) are promoted as a less risky alternative to conventional cigarettes and have grown in popularity. Experimental and clinical evidence suggests that they could increase the risk of myocardial infarction.

**Methods:** The National Health Interview Surveys of 2014 ($n$=36,697) and 2016 ($n$=33,028) were used to examine the cross-sectional association between e-cigarette use (never, former, some days, daily) and cigarette smoking (same categories) and myocardial infarction in a single logistic regression model that also included demographics (age, gender, BMI) and health characteristics (hypertension, diabetes, and hypercholesterolemia) using logistic regression. Data were collected in 2014 and 2016 and analyzed in 2017 and 2018.

**Results:** Daily e-cigarette use was independently associated with increased odds of having had a myocardial infarction (OR=1.79, 95% CI=1.20, 2.66, $p$=0.004) as was daily conventional cigarette smoking (OR=2.72, 95% CI=2.29, 3.24, $p$<0.001). Former and some day e-cigarette use were not significantly associated with having had a myocardial infarction ($p$=0.608 and $p$=0.392) whereas former (OR=1.70, $p$<0.001) and some day cigarette smoking (OR=2.36, $p$<0.001) were. Odds of a myocardial infarction were also increased with history of hypertension (OR=2.32, $p$<0.001); high cholesterol (OR=2.36, $p$<0.001); and diabetes (OR=1.77, $p$<0.001); and age (OR=1.65 per 10 years, $p$<0.001). Women (OR=0.47, $p$<0.001) had lower odds of myocardial infarction.

**Conclusions:** Daily e-cigarette use, adjusted for smoking conventional cigarettes as well as other risk factors, is associated with increased risk of myocardial infarction.

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## INTRODUCTION

Electronic cigarettes (e-cigarettes), which deliver an aerosol of (usually) nicotine and other flavors by heating a liquid, are often promoted as a safer alternative to conventional cigarettes, which generate the nicotine aerosol by burning tobacco.[1,2] Both e-cigarettes and conventional cigarettes deliver ultrafine particles that are one to two orders of magnitude smaller than a human hair,[1–5] which in smoke and air pollution increase risk of cardiovascular disease and acute myocardial infarction (MI) with a nonlinear dose–response curve.[6,7] MI risk drops when people stop smoking conventional cigarettes or stop being exposed to secondhand smoke.[8,9] E-cigarette and traditional cigarette smoking in healthy smokers with no known cardiovascular disease exhibit similar inhibition of endothelial function as measured by flow-mediated dilation of arteries,[10] shift in cardiac autonomic balance toward sympathetic predominance,[10,11] and increased oxidative stress,[10,11] which are associated with increased cardiac risk.[12,13] There is also increased oxidative stress in both e-cigarette users and conventional cigarette smokers.[10] Laboratory studies done with e-cigarette extracts found that e-cigarette use increases the release of inflammatory

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mediators from keratinocyte, alveolar epithelial cell lines, and neutrophils.[14] E-cigarette aerosol also induces platelet activation, aggregation, and adhesion.[15] In mice, chronic whole body exposure to e-cigarette aerosol accelerates aortic stiffness, significantly impairs aortic endothelial function, and may lead to impaired cardiac function.[16] These observations led the authors to hypothesize that e-cigarette use would be associated with increased risk of acute MI.

## METHODS

### Study Population

The National Health Interview Survey (NHIS), a survey of people aged ≥18 years, is conducted by the U.S. Census Bureau using in-person interviews in a random sampling of U.S. households.[17] Data from the 2014 and 2016 NHIS were used.

### Measures

Subjects who answered *yes* to the question *Have you EVER been told by a doctor or other health professional that you had a heart attack (also called myocardial infarction)?* were classified as having had an MI.

The full model includes current and former e-cigarette use and cigarette use as separate variables in the same model together with demographic (sex, age, BMI, race/ethnicity) and clinical covariates for MI (hypertension, diabetes mellitus, high cholesterol). Dual users were indicated by the concurrent values of the e-cigarette and cigarette variables rather than as a separate category.

Subjects who answered *no* to *Have you ever used an e-cigarette, even one time?* were classified as never users. Subjects who answered *yes* were then asked, *Do you now use e-cigarettes every day, some days, or not at all?* Subjects who responded *not at all* were classified as former users and those who selected *some days* and *every day* were classified as some day users and daily users, respectively.

Subjects were classified as never smokers if they answered *no* to the question *Have you smoked at least 100 cigarettes in your ENTIRE LIFE?* Subjects were classified as former smokers if they had smoked >100 cigarettes but answered *not at all* to *Do you NOW smoke cigarettes every day, some days or not at all?* The remaining subjects were classified as some day smokers and daily smokers.

Demographic characteristics in the analysis were sex and age at time of survey. These data were obtained by asking the subjects, *Are you Male or Female?* And, *How old are you?* BMI was obtained and calculated based on each subject's height (*How tall are you without shoes?*) and weight (*How much do you weigh without shoes?*). Race/ethnicity was classified as Hispanic, non-Hispanic white, non-Hispanic black, non-Hispanic Asian, or other.

This study assessed the diagnosis of hypertension, high cholesterol, and diabetes mellitus from those who answered *yes* to the questions: *Have you EVER been told by a doctor or other health professional that you had...* (1) *hypertension, also called high blood pressure, high cholesterol*, or (2) *diabetes or sugar diabetes?* respectively. For diabetes, people who responded *no* or *borderline or prediabetes* were coded as no. People who refused, were not asked, or did not know were coded as missing.

### Statistical Analysis

Descriptive statistics (means and SDs for continuous variables and frequency tables for categorical variables) were computed and one-way ANOVA and chi-square were used to test for differences between never, former, and current e-cigarette users.

Logistic regression was used to estimate the odds of having had an MI as a function of e-cigarette use, cigarette smoking, and the other covariates listed above in a single logistic regression. This approach concurrently estimates both the effects of e-cigarette and cigarette use at the same time while controlling for the other product use. The reference condition for both e-cigarette use and cigarette smoking is people who never used e-cigarettes or cigarettes.

There was no evidence of multicollinearity in the fully adjusted models (all variance inflation factors ≤ 1.45). Interaction between cigarette and e-cigarette use was tested using a variable that was set to 1 for respondents who currently used both cigarettes and e-cigarettes (0 otherwise); this interaction term was not significant ($p$=0.214), so the final logistic regression model does not include an interaction. The lack of a significant interaction suggests that the effects of e-cigarettes and conventional cigarettes on having had an MI are independent of each other.

Subjects with missing data (0.58%) were not included in the final analysis, leaving an analytic sample size of 69,046 for the multivariable analysis.

Analyses were performed using Stata, version 14.2, accounting for the complex survey design of NHIS and following NHIS procedures for combining the 2014 and 2016 data sets.[18] Data were collected in 2014 and 2016 and analyzed in 2017 and 2018.

## RESULTS

Demographic and health characteristics for subjects who used e-cigarettes are shown in Table 1. (Appendix Tables 1 and 2 [available online] contain the results for 2014 and 2016 separately.) The analysis of combined data showed that 25.8% of current (some days or daily) e-cigarette users were former smokers and 66.2% of current e-cigarette users were current (some days or daily) cigarette smokers.

Current e-cigarette users were less likely to be daily users (34.4% or 776/2,259) than were current cigarette smokers (76.5% or 8,969/11,718, $p$<0.001).

Both unadjusted and adjusted models of the combined data showed that odds of having had an MI is about 1.7 for daily e-cigarette users compared with subjects who had never used e-cigarettes, suggesting that the effect was independent of cigarette smoking status (never, former, some days, daily), demographic factors, and other health conditions (Table 2 and Figure 1, Appendix Tables 3 and 4 [available online] contain the analyses of the 2014 and 2016 data separately). Neither former nor some day e-cigarette use are associated with increased risk of MI ($p$=0.608 and $p$=0.392).