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Brief report

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Electronic Cigarettes Are a Source of Thirdhand Exposure to Nicotine

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Abstract

Introduction: Substances remaining on the surfaces in areas where people have smoked contribute to thirdhand exposure. Nicotine from tobacco smoke has been shown to react with oxidizing chemicals in the air to form secondary pollutants, such as carcinogenic nitrosamines. While previous studies have demonstrated thirdhand exposure to nicotine from tobacco smoke, none have investigated whether nicotine from electronic cigarettes (e-cigarettes) can also be deposited on various surfaces.
Methods: Three brands of e-cigarettes were refilled with varying nicotine concentrations. We released 100 puffs from each product directly into an exposure chamber. Surface wipe samples were taken from 5 indoor 100 cm^2 surfaces (window, walls, floor, wood, and metal) pre- and post-release of vapors. Nicotine was extracted from the wipes and was analyzed using gas chromatography.
Results: Three of the 4 experiments showed significant increases in the amount of nicotine on all five surfaces. The floor and glass windows had the greatest increases in nicotine, on average by a factor of 47 and 6, respectively ($p < .05$). The average amount of nicotine deposited on a floor during each experiment was 205 $\mu g/m^2$ and varied from limit of quantitation to 550 $\mu g/m^2$.
Conclusions: This study indicates that there is a risk for thirdhand exposure to nicotine from e-cigarettes. Thirdhand exposure levels differ depending on the surface and the e-cigarette brand. Future research should explore the potential risks of thirdhand exposure to carcinogens formed from the nicotine that is released from e-cigarettes.

Introduction

Electronic cigarettes (e-cigarettes) are new battery powered devices that resemble tobacco cigarettes but which convert a nicotine solution (e-liquid) into an inhalable vapor, thus eliminating a majority of the toxic effects of smoking. They were designed as smoking cessation devices by satisfying both nicotine addiction and physical habits. E-liquid contains nicotine, water, and propylene glycol and/or vegetable glycerin, which help create a vapor. The e-liquid is vaporized by a metallic coil heated by a battery that is activated when the user takes a puff on the e-cigarette.

Thirdhand exposure occurs when nicotine and other chemicals from secondhand smoke deposits on surfaces, such as walls, tables, floors, and even clothes, exposing people via touch, ingestion, and inhalation.[1–4] Thirdhand exposure is pervasive wherever nicotine has been smoked, creating multiple exposure routes. Children and infants are especially vulnerable due to their increased exposure to these surfaces and sensitivity.[1,4] The potential danger of thirdhand exposure to tobacco smoke continues long after smoking has ceased, even for years.[3] Nicotine is incredibly difficult to remove from surfaces and must be done with an acidic cleanser (most soaps are alkaline).[3,4] While it may be possible to use an acidic cleanser on walls, it may be impossible to use it on a carpet. Nicotine from tobacco smoke has been shown to react with oxidizing chemicals in the air to form secondary pollutants, such as carcinogenic nitrosamines.[5]

Despite the small emissions of nicotine from e-cigarettes as compared to tobacco cigarettes,[6] e-cigarettes might be a source of particles and organic compounds that can contaminate the air and expose children and nonsmokers. Because e-cigarettes have just entered the market, there is little research on them, and even less information on how they may contribute to thirdhand exposure. The goal of this research was to assess the deposition of nicotine on various surfaces as a marker of thirdhand exposure from e-cigarettes, using wipe sampling to take surface samples before and after e-cigarette usage.

Materials and Methods

Products

Four experiments were conducted using four different products: (a) eGo reusable tank system e-cigarettes (Shenzhen Joyetech) refilled with Ecto Cooler liquid, 24 mg/ml nicotine, orange and tangerine flavor (Crystal Canyon Vapes); (b) eGo reusable tank system e-cigarettes (Shenzhen Joyetech) refilled with Bubblegum eJuice, 32 mg/ml nicotine, bubble gum flavor (GoodeJuice.com); (c) 801-T e-cigarette nicotine (Shenzhen Yunsenya) refilled with Ecto Cooler liquid, 24 mg/ml nicotine, orange and tangerine flavor (Crystal Canyon Vapes); and (d) Blu disposable e-cigarette, 20–24 mg nicotine, classic tobacco flavor (Lorillard Technologies). Products were selected based on their internet popularity in summer 2013.

Generation and Release of the Vapors

All experiments were conducted in a 3.7 × 3.0 × 2.7 m exposure chamber with a negative pressure inside, controlled ventilation and humidity. Prior to experimentation, the ventilation system in the exposure chamber was put on high power for 15–20 min. The door to the exposure chamber was closed and the ventilation system was turned off. All experiments were performed during summer season in July and August 2013.

E-cigarette vapor was generated by attaching the e-cigarette to a 100 mL syringe via rubber connector located 1.7 m above the floor (i.e., at approximate mouth height). A puff of 100 mL was drawn into the syringe for a consistent 4–5 s. The syringe was detached from the rubber connector and whole vapor from inside of the syringe was slowly released into the exposure chamber. This procedure was repeated 10 times for one set of ten sets with 30-s intervals between puffs and 5-min intervals between sets of puffs. Thus, altogether 100 puffs were released over approximately 1.5 hr. The eGo tank system was activated manually 1 s before each puff by pressing the heating element activation button following its release immediately after aspiration of the puff.

Surface Wipes Collection

Wipe samples were collected from five different surfaces located in an exposure chamber: the tiled floor, flat glass window, vinyl wall, metal plate, and wooden desk. All surfaces except for the floor were in a vertical position approximately 1 m away from the operator of the e-cigarettes. Before each experiment, all surfaces underwent a rigorous cleaning process by wiping them 10 times with methanol and 70% isopropyl alcohol (both of HPLC grade).

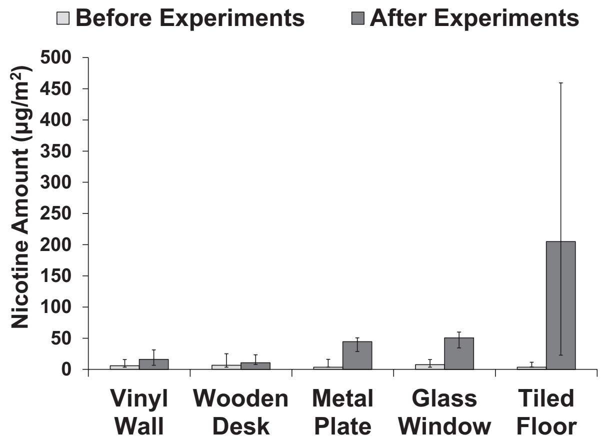

Figure 1. Amounts of nicotine deposited on various surfaces before and after exposure to e-cigarette vapors (median values; bars show interquartile ranges; *N* = 4).

Wipe samples (KimWipes) were taken as described previously by Quintana et al.[7] Briefly, templates with a 10 × 10 cm² opening area were attached onto each surface. The area inside the template was wiped using a left to right pattern and then an up and down pattern twice. Two wipe samples were collected from each surface during all experiments: the first sample was taken just before release of the vapor (baseline) and the second sample was taken 2 min after release of last portion of the vapors (see below). After each experiment was completed, wipes were placed in separate tubes and analyzed as described below.

Sample Analysis

Each wipe was spiked with 5 µL of solution of internal standard (20 µg/mL quinoline in methanol). Nicotine was extracted from the wipes by vigorously vortexing the tubes with 5 mL methanol for 5 min. Samples were analyzed using gas chromatography with a nitrogen-phosphorus detector (GC-NPD 7890B, Agilent Tech). Chromatography conditions were the same as specified in NIOSH standard method for nicotine determination in air.[8] The calibration and control samples were generated by spiking wipes with known amounts of nicotine in a range from 0.05 to 10 µg and following the above described extraction procedure. The calibration curve was linear in the whole range of nicotine (r^2 = 0.9981) and the lowest limit of quantitation (LLOQ) was 5 µg/m². The average recovery of nicotine was 106%.

Statistical Analysis

Results were calculated as nicotine amount deposited on surface area of 1 m² (µg/m²). Amounts of nicotine deposited on surfaces after exposure to vapors were compared with baseline (pre-exposure) values using Wilcoxon paired test. Values below LLOQ were calculated as LLOQ/√2 and included in the statistical analysis. For all tests, Statistica version 10.0 (Statsoft) software was used.

Results

Three out of four experiments showed a significant increase in the amounts of nicotine deposited on all surfaces ($p < .05$). The average amounts of nicotine detected on various surfaces before and after release of vapors are presented on Figure 1. The floor and glass windows had the greatest increases in nicotine, on average by a factor of 47 and 6, respectively ($p < .05$). The highest amounts of nicotine post exposure were detected on the floor and increased from undetectable levels (below LLOQ) to a median value of 205 µg/m^2 (IQR 23–460 µg/m^2; $p = .0679$) and varied from LLOQ to 550 µg/m^2.

Discussion

Our work suggests that thirdhand exposure to nicotine is possible not just from tobacco cigarettes, but also e-cigarettes. We showed that nicotine from e-cigarettes can stick to various surfaces. Surface textures, absorbency, and location might affect nicotine concentrations.

Sources of variability in nicotine levels released from e-cigarettes and deposited on indoor surfaces are yet to be fully understood. We previously found that various brands of e-cigarettes emitted different amounts of nicotine.[9,10] Different product characteristics may affect the properties of the vapor. Larger e-cigarettes may create a vapor with larger droplets that are more likely to fall to the floor. Differences in e-liquid ingredients and manufacturing may also affect the ability of nicotine solutions to stick to surfaces. Thus, the potential thirdhand exposure to nicotine from e-cigarettes may be also affected by product characteristics. Different products may expose bystanders to various amounts of nicotine.

We found significant variations in nicotine amounts deposited on different surfaces exposed to e-cigarette vapors. Nicotine sorption in an indoor environment has been showed to be affected by surface parameters, including surface area and its polarity.[11] In addition to sorption effect, subsequent desorption of nicotine from indoor surfaces to air has been shown to contribute to secondhand exposure.[12] Additional research is needed to investigate the effects of other indoor sorbents, such as fabrics, wallboard paper, and clothing on sorption and desorption of nicotine aerosol exhaled by e-cigarette users. Some variations could also be due to other factors such as cleaning, room volume, and ventilation.[13] Finally, future studies need to explore thirdhand exposure to nicotine in settings where tobacco and electronic cigarettes are used at the same time (so called "dual use").

Our study is preliminary and has important limitations. Due to small sample size and significant variations between tested products we were not able to analyze effects of product and surface characteristics on the deposited amounts of nicotine. Secondly, we released only 100 puffs from each product in relatively short time and surface wipe samples were taken shortly after vaporization of the e-liquid. Nicotine may accumulate on the surfaces, thus future research should study if more nicotine would stick to the surfaces over longer periods of time. We exposed various surfaces in controlled laboratory settings. The conditions used in our study are not the same as those in an e-cigarette user's home. These conditions include patterns of products use and puffing topography. Future research should explore the risks of thirdhand exposure from e-cigarettes in the homes of e-cigarette users and in public places and worksites where e-cigarette smoking occurs. Moreover, we did not investigate the effect of exhaled vapors by the users of the products but simulated exposure conditions by releasing vapor manually. Finally, post-exposure samples were taken from the same place as the pre-exposure (baseline) wipes. Further research should take blanks and samples from areas immediately next to each other. Regardless of the limitations listed above, we provided novel findings showing a potential risk that nicotine released from e-cigarettes may be deposited on various surfaces. Future research should explore the risks of thirdhand exposure from e-cigarettes and assess thirdhand exposure in "real-life" conditions outside laboratory settings.

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Declaration of Interest

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