

Electronic cigarettes (e-cigs): views of aficionados and clinical/public health perspectives

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SUMMARY

Background: Electronic cigarettes (e-cigs) have experienced a rapid growth in popularity but little is known about how they are used. **Aim:** The aim of this study was to identify the e-cig products used by experienced e-cig users, their pattern of e-cig use and the impact on tobacco use. **Method:** Face-to-face survey of 104 experienced e-cig users. **Results:** Of all the e-cig users, 78% had not used any tobacco in the prior 30 days. They had previously smoked an average of 25 cigarettes per day, and had tried to quit smoking an average of nine times before they started using e-cigs. Two-thirds had previously tried to quit smoking using an FDA-approved smoking cessation medication. The majority of the sample had used e-cigs daily for at least a year. Three quarters started using e-cigs with the intention of quitting smoking and almost all felt that the e-cig had helped them to succeed in quitting smoking. Two-thirds used e-cig liquid with a medium to high concentration of nicotine (13 mg +). Only 8% were using the most widely sold types of cigarette-sized e-cigs that are typically powered by a single 3.7 volt battery. Instead most used e-cigs designed to enable the atomizer to more consistently achieve a hotter more intense vapour. **Conclusion:** Until we have more evidence on the safety and efficacy of e-cigs for smoking cessation, smokers should be advised to use proven treatments (e.g. counselling and FDA-approved medicines). However, for those who have successfully switched to e-cigs, the priority should be staying off cigarettes, rather than quitting e-cigs.

Introduction

Electronic cigarettes (e-cigs) in the current form were invented by Chinese pharmacist Hon Lik in 2003 with patents held by the Ruyan company. Exports of e-cigs from China continue to rise despite legal challenges regarding their regulatory status (tobacco product, medical drug delivery device, or neither) and sales (mainly online) have continued to grow. One recent study reported that by September 2010 internet searches for e-cigs were several-hundred-fold greater than searches for nicotine replacement therapy products (1). However, despite the rapid rise in popularity of these products, remarkably little is known about e-cigs, how they are used, what substances are in them and what substances are delivered to the user and the environment.

Figure 1 shows a typical e-cig setup for a breath-activated (pneumatic) inhalation. The cartridge holds a liquid mixture typically containing propylene glycol and nicotine. Inhalation activates a pressure-sensitive

circuit that heats the atomizer and turns the liquid into a vapour which is drawn through the mouth-piece. The vapour is a fine mist without smoke or carbon-monoxide, which dissipates more quickly than smoke. Many e-cigs are designed for the tip of the e-cig to light up during inhalation and more recently some have been designed to light up blue rather than red to show that this is not really a cigarette (Figure 1).

Two published studies have measured the blood nicotine levels resulting from e-cig use and, contrary to expectations, both studies found that even e-cigs labelled as 'high nicotine', produced remarkably low nicotine absorption. Bullen et al. (2) found that whereas smokers obtained a fairly typical blood nicotine concentration of 13.4 ng/ml from smoking a single cigarette, they obtained only 1.3 ng/ml from use of a Ruyan V8 e-cig, using a cartridge labelled as containing 16 mg of nicotine. Despite the very low nicotine delivery, the participants reported that the 'high nicotine' e-cig resulted in less desire to smoke

What's known

The popularity of electronic cigarettes (e-cigs) is increasing rapidly. They deliver a vapour of propylene glycol and nicotine, without any smoke.

What's new

Some e-cig users are continuing to use e-cigs long term, primarily as a way of ending their tobacco use. These experienced e-cig users tend to use e-cigs that are larger than the mass-marketed cigarette-size e-cigs. Rather, they use e-cigs that are designed to provide more intense vapour via stronger battery power.

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Disclosures

None of the authors have any financial connections with the tobacco or electronic cigarette industries. JF has worked as a paid consultant for companies involved in the production of pharmaceutical products as aids to smoking cessation (e.g. Cypress Bioscience, GSK, Novartis, Pfizer).

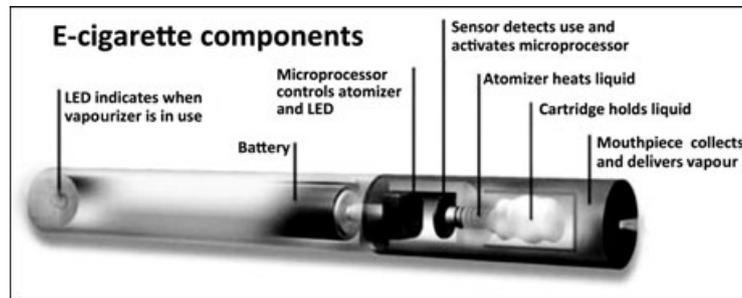


Figure 1 Typical components of an electronic cigarette

than an e-cig containing a zero nicotine cartridge and was rated as more pleasant to use than the pharmaceutical nicotine inhaler (Johnson & Johnson Inc., New Brunswick, NJ, USA). Vansickel et al. (3) found that whereas smoking two regular cigarettes resulted in a peak blood nicotine increase from 2.1 ng/ml to 18.8 ng/ml, two 5-min puffing sessions with either the NPRO (NJOY, Scottsdale, AZ, USA) or HYDRO (Crown Seven, Scottsdale, AZ, USA) e-cigs loaded with 16–18 mg nicotine cartridges, resulted in very low blood nicotine levels (3.5 ng/ml and 2.5 ng/ml respectively). In contrast to cigarette smoking, ‘vaping’ an e-cig produced no increase in exhaled carbon-monoxide levels. It should be noted that both of these studies involved providing e-cig naïve cigarette smokers with e-cigs of the researchers’ choosing and asking volunteers to use it, like a cigarette. However, more recently Vansickel et al. (4) reported (as yet unpublished) preliminary results from a study in which experienced e-cig users were allowed to use their own (customised) e-cigs. In this study, two of three initial participants achieved rapid increases in blood nicotine concentration with a similar order of magnitude and speed as a cigarette (> 10 ng/ml in 5 min).

These early signs of different results in experienced e-cig users (when compared with e-cig naïve smokers) suggest that we may learn useful information about e-cigs from these individuals, including a better understanding of the characteristics of the e-cigs they choose and their patterns of use. This paper reports on results of a face-to-face survey study of experienced e-cig users attending a meeting for e-cig aficionados, describes the e-cig products they use and discusses public health issues raised by these products and implications for clinicians.

Method

The survey took place during the first 3-hour session of a meeting of electronic cigarette enthusiasts in Philadelphia, USA (‘Philly Vapefest, 2011’). The investigator (JF) informed attendees that the aim of

the study was to help understand e-cigarette use. Completion of the questionnaire was anonymous, approved by the Institutional Review Board at Penn State Hershey, and involved a 55-item questionnaire covering (i) demographics, (ii) e-cig use history (iii) tobacco use history and (iv) beliefs about e-cigs.

A total of 129 people attended this part of the meeting and 110 questionnaires were handed out. A total of 105 questionnaires were returned, one of which was not included in the data analysis presented here as the participant was not an e-cig user.

Analysis

We provide descriptive statistics for the participants’ answers, plus statistical comparisons between the short-term (< 12 month) e-cig users ($n = 48$) and the long-term (1 year or more) e-cig users ($n = 56$). Standard statistical tests (including chi-squared test for categorical variables, independent *t*-test for normally distributed variables, and the Mann–Whitney *U*-test for skewed data) were used to compare those two groups. Statistical analyses were performed with spss version 18 (SPSS Inc. Chicago IL, USA).

Results

Table 1 shows the basic descriptive data for the whole sample and also compares those who have used e-cigs for less than a year, with those who have used them for a year or more. The majority were male, employed full-time and had not used a tobacco product within the previous month. All had previously used tobacco but one had never been a regular tobacco user; 88% of the participants described themselves as ex-cigarette smokers (some had switched to smokeless tobacco or cigars prior to trying e-cigs) and overall they had been heavy smokers, smoking 25 cigarettes per day, smoking within a half hour of waking in the morning. They had tried to quit smoking an average of nine times before they started using e-cigs and two-thirds had previously tried to quit smoking by using an FDA-approved smoking cessation medication.

Table 1 Characteristics of experienced e-cigarette users and comparison between those who have used for greater than and less than 1 year

Characteristic (n)	Total sample (n = 104)	Use e-cig < 1 year (n = 48)‡	Use e-cig ≥ 1 year (n = 56)	p-value*
% Male (103)	74	72	75	0.760
% White (104)	88	90	86	0.552
% with college degree (102)	40	38	42	0.718
Mean Age (104)	34 ± 8.8	33 ± 8	34 ± 9	0.451
% employed full-time (102)	77	69	83	0.083
% making > 10% income from e-cig business (104)	13	4	20	0.017
Median days since last tobacco product use (102)	150 (0–1234)	90 (0–556)	365 (0–1234)	< 0.0001
% currently use smoked tobacco (104)	12	13	11	0.776
% who have not used tobacco in past the 30 days (102)	78	75	82	0.368
% whose last tobacco product was a cigarette (103)	95	98	93	0.238
Mean years used tobacco (102)	16 ± 10	16 ± 9	17 ± 10	0.521
Mean cigarettes per day (103)	25 ± 13	24 ± 11	26 ± 15	0.086
Time to first smoke of day, in minutes (100)	24 ± 47	18 ± 22	30 ± 61	0.202
Time to first use of e-cig, in minutes (101)	38 ± 38	33 ± 36	42 ± 40	0.238
% woke at night to smoke (104)	49	56	43	0.173
Mean number of quit attempts (91)	9 ± 16	9 ± 16	10 ± 15	0.843
% saying 'extremely important' to stay off tobacco (104)	90	88	93	0.356
% saying 'extremely confident' they can succeed in staying off tobacco (104)	93	94	93	0.856
% previously used an FDA-approved smoking cessation medication (104)	65	67	64	0.799
% previously tried ≥ 2 FDA-approved smoking cessation medications (104)	54	54	54	0.952
% tried to quit 'cold turkey' (104)	73	67	79	0.172
% tried to quit by using smokeless tobacco (104)	21	27	16	0.170
% using an e-cig ≥ 20 days out of the past 28 (103)	89	92	88	0.514
Mean length of e-cig use in months (104)	13 ± 9	5 ± 3	20 ± 7	< 0.0001
% use e-cig liquid > 12 mg concentration (102)	66	83	51	0.001
% who believe they get more or the same amount of nicotine from an e-cig (102)	58	67	50	0.089
% who agree with the following reasons for personal use of e-cig rather than a regular cigarette (104)				
I believe the e-cig is less harmful to others	80	73	86	0.105
I believe it is less harmful to my health	98	100	96	0.186
I prefer the taste	80	71	88	0.035
I can use an e-cig in places where smoking is banned	64	67	63	0.658
% have a preferred type of e-cig (104)	79	75	82	0.374
% who believe they inhale e-cig less deeply than cigarettes (44)	34	40	29	0.450
% who believe they use e-cig the same or more frequently than cigarettes (83)	35	45	26	0.064
Median times e-cig used per day (82)	20 (2–60)†	20 (2–60)	20 (2–60)	0.588
% who are able to use an e-cig in places where smoking is banned (104)	90	92	89	0.681
% who started e-cig use with the intention of quitting tobacco soon (103)	73	75	71	0.730
% who believe e-cig helped them quit smoking (102)	99	98	100	0.277
% who plan to continue using e-cig for at least another year (103)	89	94	86	0.174
Median cost of current e-cig in US \$ (94)	70 (8–235)	61 (8–235)	80 (20–180)	0.042
Mean weekly cost to maintain vaping, US \$ (93)	13 ± 10	12 ± 6	13 ± 12	0.455

Means are expressed as the mean ± standard deviation. Medians are expressed as the median (range). *Differences between means were evaluated by two sample *t*-tests; proportions were evaluated by chi-square tests; differences between the medians were evaluated with Mann–Whitney test. †Does not include 23 individuals who reported they used their e-cig a 'countless' number or '100 s' of times per day. Respondents who reported using their e-cig more than 60 times per day were coded as 60. ‡The total *n* for each group varies depending on number who responded to each individual question.

The majority of the respondents had used e-cigs for at least a year and used it on a daily basis. When asked to estimate the number of uses per day, with each use defined as '10 min or 10–20 puffs', the med-

ian number of uses was 20. Participants mentioned that this question was difficult to answer because, unlike a cigarette that is generally smoked as a whole and then discarded, e-cigs can be used more fre-

quently but with fewer puffs per session, because there is no need to 'finish the cig' in one sitting. Most (73%) started using e-cigs with the intention of quitting smoking and almost all (99%) felt that the e-cig had helped them to succeed in quitting smoking.

Two-thirds used e-cig liquid with a medium to high concentration of nicotine (13 mg +/-cartridge). As shown in Figure 2, all of those who felt that they absorbed more nicotine from their e-cig than from their cigarettes (who were in the minority) used e-cig liquid with a concentration of over 12 mg.

There were few differences between those who have used e-cigs for less than a year and those who have used for longer, perhaps because the 'short-term users' in this sample were themselves relatively experienced users (median 5 months). Surprisingly, the long-term users typically used slightly lower nicotine strength liquid.

One interesting finding was that very few of the participants (8%) in this survey were using the most

widely sold types of e-cigs, that are the same size as a regular cigarette, often powered by a single rechargeable 3.7 volt AAA-sized battery, and using replaceable screw-in e-liquid cartridges (often sold under brand names such as 'NJOY' and 'Smoking Everywhere' in USA). Table 2 shows that the vast majority of experienced e-cig users were using e-cig models that were generally larger in size, with higher voltage battery power [referred to by users as 'personal vapourizers' (PVs)]. The majority of long-term users were using e-cigs that had modified battery housing (usually to accommodate multiple or larger batteries), whereas the majority of those who have used for less than a year were using a model of e-cig that had been launched in the U.S.A. 10 months prior to the survey and had a large/long life proprietary battery.

Discussion

The results of this face-to-face survey of experienced e-cig users are broadly consistent with previous online or e-mail based surveys of e-cig users in finding that a high proportion have completely replaced cigarette smoking with e-cig use (5–8). Etter and Bullen (8) found that the cigarette-shaped models that had been tested in previous studies were seldom used by respondents in their large online survey. Among 3037 ever-users of e-cigs, 77% used e-cigs to quit smoking or avoid relapsing and 20% stated that they used e-cigs to reduce tobacco consumption with no intention of quitting smoking. Most of the ex-smokers in that study (79%) feared that they might relapse to smoking if they stopped using the e-cig.

The present study differed from prior e-cig studies by focusing on experienced long-term users, with the

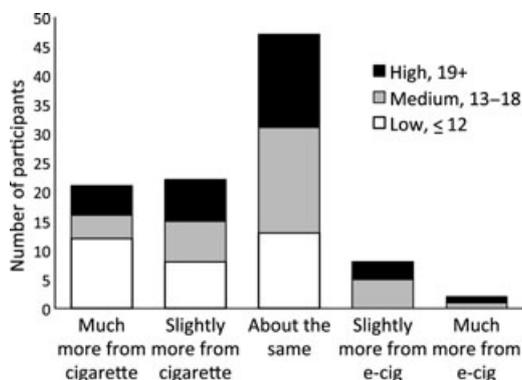


Figure 2 Comparison of perceived nicotine absorption from e-cig vs. regular cigarette in experienced e-cig users by strength of nicotine used (mg per cartridge)

Table 2 E-cigarette model use for those who have used an e-cig for less than 1 year and for those who have used for 1 year or more*

Model of e-cig (n)	Total sample (n = 98)	Use e-cig < 1 year (n = 45)	Use e-cig ≥ 1 year (n = 53)
% who use a modified battery housing PV (3.7/6 v) (e.g. Omega, Silver Bullet, Helix) (38)	39	20	55†
% who use a 5 v regulated battery modification PV (e.g. Triple V, Tekk Mod) (6)	6	9	4
% who use a variable voltage modification PV (e.g. Provari, Eclipse) (6)	6	7	6
% who use a large/long-life proprietary battery PV (e.g. eGo, Joye, Riva) (37)	38	53	24
% who use a standard 3.7 v e-cig (e.g. NJoy, Magma) (8)	8	9	7
% who use a multiple voltage battery compatible modified PV (3.7/5/6/7.4) (e.g. Megalodon) (3)	3	2	4

*PV, personal vaporizer. †Significantly more long-term e-cig users than short-term using modified battery housing PVs (p = 0.001).

majority having used e-cigs for over a year. It also differs from prior studies in that the survey was completed in person rather than online (avoiding potential repeat completion by motivated activists). One interesting finding was that comparatively few of these e-cig aficionados are using the most widely marketed and sold types of e-cigs. Instead, they frequently use e-cigs with characteristics that appear designed to enable the atomiser to achieve a higher and more consistent temperature, resulting in a hotter, more intense vapour. This can be done in a number of ways, including (i) using more powerful (often larger) batteries, (ii) using batteries that last longer (and so produce consistent high heat for each use throughout the day), (iii) using a manual switch to initiate the atomiser prior to inhalation and enable a longer inhalation if necessary (pneumatic/airflow activation may result in the inhalation taking place before the atomiser had achieved a sufficient temperature).

It is possible, but remains to be confirmed by future studies, that these differences in characteristics of various e-cigs may at least partially explain the differences in nicotine absorption found in the initial studies(4). These differences may also relate to user experience with the products. For example, some users of standard cigarette-shaped e-cigs with 3.7 v batteries learn to 'prime' (or preheat) the atomiser prior to inhalation by taking a priming puff a few seconds prior to the puff they intend to inhale.

Public health perspective

As e-cigs are largely sold via the internet, it is difficult to estimate total sales and use rates. However, in a legal case against the U.S. FDA, *Smoking Everywhere*, reported selling 600,000 e-cigs in just over a year, and *NJOY* reported selling 135,000 in the United States (9). In a prospective survey by Siegel et al.(5), the initial sampling frame was reported as consisting of purchasers of a new e-cig from one company (*BLU*) over a 2-week period and consisted of 5000 new customers. An unpublished study in the U.K. found that 9% of smokers had used e-cigs and 3% were still using them (10). These figures, combined with the evidence of growing public interest in e-cigs based on internet searches, suggest that they could potentially have a public health impact. Clinicians will more frequently see patients who are e-cig users and will have to assess the potential impact on the individual patient's health. One inquest into the death of an e-cig user in the United Kingdom has already been widely reported (11).

As in previous studies, most of the participants in this study used e-cigs as a way to quit smoking and

because they perceive it to be much less harmful to their health than smoking. So the key questions are whether these products really help smokers to quit, and relative to both tobacco use, and existing smoking cessation medicines, whether the e-cigs themselves have their own health risks.

To date there are no published randomised clinical trials designed to test the efficacy and safety of e-cigs as smoking cessation aids. The few published short-term laboratory studies confirm that users do not absorb carbon-monoxide (confirming that no smoke is produced), but also suggest relatively low nicotine absorption, at least in inexperienced e-cig users, using standard e-cig models. Trtchounian and Talbot (12) evaluated the design and labelling of five popular e-cig brands and noted that leaking of liquid and inadequate labelling were common. For example, the labelling of liquid/cartridges does not specify whether the stated mg of nicotine is per cartridge or per millilitre. They concluded that regulation of manufacturing, quality control, sales and advertisements of e-cigs is needed.

In May 2009, the U.S. FDA announced the results of analyses of two leading brands of e-cigs and comparison with the FDA-approved Nicotrol Nicotine Inhaler (13). They found that concentrations of nicotine were approximately proportional to the labelling (zero, low, medium and high), with some inconsistencies, and that a 100 ml puff on a 'medium' nicotine e-cig contained a similar amount of nicotine as a puff on the Nicotrol inhaler. The analyses also detected the presence of some impurities in the e-cig liquid, (e.g. tobacco specific nitrosamines and diethylene glycol), albeit at low levels. At that time, the FDA expressed concern about quality control and labelling accuracy of e-cigs. Following a court ruling, in April 2011, the FDA announced that it will not attempt to regulate e-cigs as drugs/devices (unless manufacturers make health claims or seek approval via that route), but rather will develop a strategy to regulate them as tobacco products.

Other studies have detected additional impurities in e-cig liquid or vapour, (e.g. polycyclic hydrocarbons, aldehydes, acrolein and glycerol), although generally at much lower concentrations than are found in cigarettes and on occasions e-cigs have been advertised as containing other drugs (e.g. tadalafil and rimonabant) (14,15). Propylene glycol (the primary vehicle in e-cig liquid) is generally considered safe in food. It is sometimes used as the vehicle in both inhaled and injected medicines (e.g. cyclosporine and lorazepam) (16,17).

Additional public health concerns include: (i) never-tobacco users may initiate nicotine use with e-cigs, (ii) e-cigs may be used mainly in places where

smoking is banned and so help smokers continue their nicotine addiction by becoming a dual user, (iii) e-cigs may pose unknown health problems, such as via long-term inhalation of propylene glycol or inadvertent poisoning of a child consuming flavoured e-cig liquid (iv) e-cigs are unproven as smoking cessation aids and may be used in place of medicines that have been proven to be safe and effective for smoking cessation (18).

There is clearly an urgent need for research to establish the safety profile of e-cigs and if this is demonstrated to be acceptable, to assess their efficacy as smoking cessation aids in appropriately designed clinical trials (15).

Clinical perspective

It is likely that before such research evidence is available, practising clinicians will begin to see patients who are either already using e-cigs or are considering using them for smoking cessation and may ask for advice. Current smokers who are interested in quitting smoking should be strongly directed towards evidence-based treatments (counselling, and approved medicines like nicotine replacement, bupropion or varenicline), rather than to e-cigs (19). Patients who have already switched to e-cigs should be informed that although it is highly likely that e-cigs are much less harmful to health than ciga-

rettes, we do not know enough about e-cigs to recommend them to patients. However, if the patient perceives that the e-cig is helping them to stay off cigarettes and is not reporting any health problems likely attributable to the e-cig, then the focus should be on staying smoke-free rather than e-cig free. The health risks from smoking are large and are known with certainty. Comparatively, the health risks from e-cig use are likely much smaller (if any) and temporarily switching to e-cigs will likely yield a large health benefit. Even in this scenario, however, it would be prudent to make clear that the effects of e-cigs are largely unknown and that the most important thing for the patient's health is complete abstinence from tobacco smoking.

Author contributions

JF conceived the study and collected the data and, together with SV and AB, participated in data analysis, interpretation and drafting of the paper.

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