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THE IMPACT OF E-CIGARETTE USE ON LUNG FUNCTION AND RESPIRATORY HEALTH

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Abstract

Given the increasing popularity of e-cigarettes (ECs), it is crucial to gather research about their impact on health in order to guide healthcare practices and policy decisions. Regulators and health experts have expressed worries that the fine particles produced by electronic cigarettes (ECs) may include various substances that might be harmful to respiratory health. We provide a thorough evaluation of published data on the respiratory system, including the impact of electronic cigarettes (ECs) on preclinical models, clinical trials involving individuals who transitioned from tobacco cigarettes to ECs, and demographic surveys. We evaluate the research based on the rigor of their methodology and the precision of their interpretation. It is crucial to prioritize the rapid development of strong and practical methodological suggestions in order to accurately evaluate the effects of EC usage on human health and solve frequent errors. The results of this analysis suggest that electronic cigarettes, when used normally, provide much less respiratory hazards compared to traditional tobacco cigarettes. Users of electronic cigarettes (ECs) and those who smoke and are contemplating using ECs have the entitlement to receive accurate information about the comparative hazards associated with EC usage. They should also be warned that the conclusions drawn from research reported in the media may not always be trustworthy. Increasing research substantiates the comparative safety of EC emission aerosols for the respiratory system in comparison to tobacco smoke.

Keywords: E-cigarette, respiratory health, nicotine, smoking, reviews.

1. Introduction

The prevalence of electronic cigarettes (ECs) has seen a substantial surge in the last decade. These consumer products have been quickly becoming more popular than traditional cigarettes because they are effective in reducing tobacco consumption, have a competitive price, are seen by consumers as a less harmful alternative to smoking, and provide a smoking-like experience without actually smoking [1–3]. Previous iterations have undergone significant changes over the last ten years, resulting in the current availability of these devices in many formats and types. Essentially, ECs are electrical devices powered by batteries that function by heating a component (often a metal coil) to convert a solution (e-liquid) mostly composed of glycerol, propylene glycol (PG), distilled water, and flavorings into vapor. This solution may or may not include nicotine. Users inhale the aerosol produced by vaporizing the e-liquid, a procedure widely known as 'vaping.' Electronic cigarettes (ECs) do not contain tobacco, do not produce smoke, and do not need combustion to function.

The composition of EC aerosol is much less intricate compared to that of cigarette smoke [4–10]. In contrast, cigarette smoke is known to include several toxic and possibly dangerous substances [11]. Several primary toxins found in cigarette smoke are also found in the emissions of electronic cigarettes (EC), albeit in far smaller quantities compared to cigarette smoke. Furthermore, these toxins are frequently present in electronic cigarette aerosol at levels that are no higher than what is typically found in the general environment.

2. Electronic cigarette (EC)

Electronic cigarette (EC) usage is considered to have lower levels of dangers compared to smoking, according to the Royal College of Physicians [12], Public Health England [13], and other sources [14, 15]. According to the RCP, electronic cigarettes (ECs) are estimated to be at least 95% less dangerous than regular cigarettes. However, there is apprehension that prolonged exposure to EC aerosol emissions may pose some health hazards. Due to the particle size of EC aerosols falling within the respiratory range [16, 17], these aerosol particles are able to enter the lungs [18], mostly affecting the airways and possibly causing adverse consequences.

Regrettably, there is a dearth of knowledge on the long-term health consequences of vaping, which is especially worrisome for those who have never smoked and have just begun using electronic cigarettes. Hence, it is essential to do research on the toxicological and biological impacts of EC aerosol emissions. This may be achieved by using in vitro human airway cell systems, animal models, and clinical investigations. The objective is to assess the possible health hazards associated with the use of these devices. The determination of whether chronic exposure to EC leads to lung disease can only be assessed through extensive, long-term investigations involving daily EC users who have never smoked. Conducting such a study at present would be difficult, as the majority of EC users have a history of prior or current cigarette smoke exposure. It is essential to effectively discourage nicotine usage among young people, which includes not just smoking but also vaping.

This review article critically evaluates published research that have examined the possible harmful effects of electronic cigarettes (ECs) utilizing preclinical models, including cell culture, animal models, and clinical trials (excluding case reports). Preclinical studies may not provide a complete indication of how the human body will react to exposure. As a result, animal studies are still necessary for regulatory toxicological testing. The recognition of in vitro models as viable alternatives is gradually increasing due to significant technical advancements. Taking into consideration these methodological concerns, we provide a comprehensive summary of the developing body of research on respiratory health discoveries. The narrative review commences by providing an overview of EC aerosols, followed by an analysis of the literature categorized according to several types of research: cell tests, animal studies, and investigations on respiratory health.

3. Components of EC aerosols

When ECs are activated, they produce aerosols that may be inhaled and include several substances that may have toxicological and biological effects on respiratory health. However, the quantities of these substances are substantially lower in EC aerosols compared to cigarette smoke. A recent extensive evaluation of EC chemical emissions revealed that out of the 150 components analyzed in the EC aerosol (which included all harmful and potentially harmful substances found in tobacco smoke, as well as other toxic species commonly found in EC emissions), 104 were not found, while 21 were detected as a result of laboratory background [9].

Out of the 25 aerosol ingredients that were still discovered, 9 were found at levels that were too low to be measured accurately. The EC developed a total of 16 substances, either whole or partially, from three sources: i) the main components of e-liquid (nicotine, PG, and VG); ii) known contaminants found in nicotine of Pharmacopoeia-quality; and iii) eight thermal breakdown products of PG or VG. In comparison, almost 100 components were identified in the smoke produced by conventional cigarettes. The EC emitted toxicants at a much reduced rate per puff compared to tobacco cigarettes, ranging from 82 to >99% reduction. While the aerosol produced by electronic cigarettes (EC) is less complicated in terms of composition compared to cigarette smoke and includes lower amounts of harmful substances, a comprehensive analysis of EC chemical emissions would need non-targeted analytical evaluations of various commercial items.

The aerosol ingredients that have received the greatest attention include glycerol, PG, their thermal breakdown products (carbonyl compounds), chemical flavorings, nicotine, and metals. The US Food and Drug Administration (FDA) and the US Environmental Protection Agency (EPA) classify vegetable glycerine (VG) and PG as Generally Recognized as Safe [19]. While PG may also be detected in cigarette smoke, it is often found in high amounts in EC aerosol emissions. Therefore, it is important to have a more comprehensive comprehension of the safety of PG when inhaled. According to several research conducted on animals and humans, the inhalation of PG does not seem to provide a substantial risk [20]. Indeed, in several animal investigations, the levels of PG used were greater than those employed in EC and did not result in any harmful consequences. Nevertheless, it is necessary to conduct human trials utilizing PG concentrations comparable to those found in ECs in order to verify the safety of inhaling PG from vaping devices.

Although glycerol and PG aerosols have a generally benign profile, studies have shown that they may have irritating effects [21–23]. The potential for chronic airway irritation to have lasting effects cannot be disregarded, and more research in this field is necessary. Moreover, PG has been linked to the development of oral allergic contact dermatitis [24], and some individuals may have signs and symptoms consistent with contact dermatitis in the vicinity of the mouth or in the oral mucosa [25].

4. Impact of electronic cigarette (EC) use on respiratory well-being

Human cell systems and animal models used in vitro are not reliable indications of the possible health hazards associated with the use of ECs. The results of clinical investigations in the majority of medical disciplines illustrate the limited efficacy of these preclinical models. When considering the issue of health impacts caused by electronic cigarettes (ECs), human studies are very significant, especially when examining the effects of ECs used in typical situations. Clear conclusions on the long-term health effects of electronic cigarettes (ECs) can only be drawn from extensive prospective studies that include a large sample size of well-defined EC users and follow them for many years. To address the difficulty of conducting multi-year studies, one possible approach is to detect early changes in subclinical injury in smokers who switch to electronic cigarettes (ECs). This can be done using highly sensitive functional tests and biomarkers that indicate lung inflammation and injury. Additionally, it may be beneficial to modify health effect indicators in EC users who already have pre-existing diseases. Furthermore, epidemiologic survey data may provide valuable insights into the effects of EC usage on respiratory health.

When smokers transition from cigarettes to electronic cigarettes (EC), they may experience temporary throat discomfort, dry cough, and other symptoms of respiratory irritation [22, 23]. The sensitive respiratory functional tests conducted by certain authors [26, 27] have revealed acute changes in the human respiratory tract when exposed to non-specific stimuli like hyperosmolar EC aerosols. Asthmatics, in particular, exhibit more intense and efficient reflex responses in such situations. The potential for acute irritation to result in clinically significant lung illness is still uncertain. However, there is no data indicating that such irritation may have harmful consequences on the lungs that are clinically significant. The minor rise in peripheral flow resistance observed immediately after EC use has uncertain significance for health outcomes. This is especially true considering that standard spirometry tests conducted in the same studies did not reveal any significant alterations immediately after EC use [26, 27]. Exposing 10 healthy persons to EC aerosols resulted in immediate alterations in the biological reactions of the small airway epithelium, alveolar macrophages, and lung capillary endothelium [28]. The significance of these immediate impacts on clinical lung illness is uncertain and can only be assessed by future extensive, long-term investigations of persons who have never smoked or currently smoke cigarettes, but have exclusively used electronic cigarettes.

Subsequent studies have shown that there is no blockage of airflow after the use of electronic cigarettes for a brief period of time [29–31]. In addition, a research lasting 5 days and including 105 healthy smokers found no notable alterations in pulmonary function (FVC, FEV1) in either the group that totally or partly transitioned from regular cigarettes to electronic cigarettes, or the group that completely stopped using tobacco and nicotine products [32]. Similarly, in a rigorous randomized control study with 387 smokers in good health, Cravo and colleagues [33]. There were no notable alterations in pulmonary function tests seen over a 12-week period among individuals who transitioned to electronic cigarettes (EC) compared to those who were randomly assigned to continue smoking. While none of the studies included here reported any significant acute respiratory symptoms after exposure to EC aerosols, it is still possible that adverse events might occur in persons who are susceptible to reacting to pollutants or by-products found in EC aerosol.

Smoking cessation may lead to improvements in pulmonary function tests, however these improvements may take a significant amount of time, perhaps months or even years, to become clinically significant. Additionally, it is important to note that these improvements are often only seen in smokers who already have airway blockage. The long-term effects of transitioning to electronic cigarettes (ECs) on respiratory outcomes are uncertain and have only been examined in a limited number of research. The 1-year randomized controlled study found no significant alteration in pulmonary function tests among smokers with normal spirometry at baseline who switched to electronic cigarettes (ECs). However, there were reported enhancements in respiratory symptoms, including cough and shortness of breath. [34] This research found a steady improvement in the function of the peripheral airways, namely the FEF 25-75%, which is a sensitive measure of blockage in the more peripheral airways, among those who entirely quit smoking cigarettes.

Smokers who entirely quit smoking have shown normalization of exhaled levels of nitric oxide (NO) and carbon monoxide (CO). According to a 1-year randomized controlled experiment [35], individuals who ceased using electronic cigarettes (ECs) or continued using ECs showed a return to normal non-smoking levels after 3 months. This return to normal levels was complete at 6 and 12 months for both groups. Conversely, people who did not succeed in quitting or reducing their cigarette smoking did not show any notable improvements. Completely refraining from smoking traditional cigarettes is known to decrease the levels of exhaled carbon monoxide (CO) to a normal range. Similar decreases in exhaled CO have been seen in both short-term and long-term investigations on electronic cigarettes (ECs). Considering that ECs are battery-powered devices that do not need combustion for operation, this outcome was not unexpected. The observed enhancements in exhaled levels of nitric oxide (NO) and carbon monoxide (CO) were linked to reductions in composite symptom ratings, including cough, phlegm, and shortness of breath, wheezing, tightness in the chest, nasal congestion, sinus discomfort, and frontal headache. These benefits were most prominent in persons who quit smoking entirely. The results have been voluntarily disclosed by a diverse range of individuals who use e-cigarettes in real-life situations [2, 25].

The amelioration of inflammatory alterations in the upper and lower respiratory tracts after smoking cessation may serve as the underlying mechanism for the observed enhancements in symptom ratings. When evaluating respiratory health, it is crucial to distinguish between the health impacts caused by long-term exposure to EC aerosol emissions and those associated with past smoking habits. Among a limited group of individuals who use electronic cigarettes (EC) on a daily basis and have never smoked, no decline in spirometric indices, emergence of respiratory symptoms, alterations in markers of lung inflammation, or indications of early lung damage on high-resolution computed tomography (HRCT) were observed in any of the nine participants who successfully completed the 3.5-year monitoring period [36]. Important limitations of this research were the small sample size, absence of a control smoking group, and relatively short length of the follow-up period.

COPD, a progressive illness, is linked to tobacco smoking. It is characterized by a chronic inflammatory and remodeling response of the airways [37, 38]. Quitting smoking is the only scientifically proven approach that may effectively change the progression of COPD and decrease the risk of death [39, 40]. Switching to electronic cigarette (EC) usage may result in significant respiratory advantages for those with chronic obstructive pulmonary disease (COPD), leading to a reduction in cigarette use. A retrospective-prospective research on patients with COPD discovered that there was no decline in respiratory physiology, namely in post-bronchodilator FEV1, FVC, and %FEV1/FVC, among COPD patients who discontinued or significantly decreased their tobacco usage by converting to electronic cigarette (EC) use [41]. It is very uncommon for smokers with COPD and irreversible airway blockage to not see substantial improvements in spirometric indices after quitting smoking [42, 43]. However, individuals included in a three-year research project saw substantial reductions in annual respiratory exacerbations, notable enhancements in general health status (evaluated using the COPD Assessment Test [CAT]), and increased physical activity (measured using the Six-Minute Walk Test) [41].

The positive impact on health outcomes has also been shown in an online study of individuals with chronic obstructive pulmonary disease (COPD) who regularly use electronic cigarettes [2]. Out of the respondents, 75.7% reported an improvement in their respiratory problems after switching, while just 0.8% reported a deterioration. Self-reported outcomes from general vapers also demonstrate a positive impact on respiratory symptoms [2, 25]. An important discovery is that COPD patients who discontinued or significantly decreased their tobacco intake by switching to ECs saw a 50% decrease in respiratory exacerbations [41]. Smoking has been shown to enhance vulnerability to respiratory infection caused by bacterial and viral pathogens, whereas stopping smoking seems to reduce the risk of respiratory infection [44-46]. Consistent use of electronic cigarettes (EC) may decrease the activity of infections [47]. This is likely because propylene glycol, found in the aerosol form of EC, has both antibacterial and antiviral properties [48 ,49]. Commercially accessible e-liquids have recently been shown to possess antibacterial action [50].

5. Conclusion

Electronic cigarettes (ECs) produce fine particles that may be inhaled, known as respirable aerosols. These aerosols include glycerol, propylene glycol (PG), and the byproducts that are formed when these substances are heated (carbonyl compounds). They also contain chemical flavorings and metals, but in considerably less quantity compared to cigarette smoke. The usage of electronic cigarettes (EC) at a dosage of 5 grams per day results in a significant decrease of 79.0-96.8% in formaldehyde exposure, 99.5-99.8% reduction in acetaldehyde exposure, and 96.0-99.5% reduction in acrolein exposure when compared to smoking 20 tobacco cigarettes. Research on the impact of inhaling PG in people has demonstrated that it does not seem to provide a substantial danger [20]. However, it is worth mentioning that exposure to glycerol and PG aerosols has been shown to cause some irritating effects [21–23].

Recently, there have been introductions of new technologies and innovations in EC design to further reduce any remaining negative effects and enhance customer pleasure. Modern devices equipped with temperature regulation features effectively avoid overheating and the occurrence of the dry-puff phenomena, which may lead to the excessive synthesis of carbonyls.

References

1. Caponnetto P, Russo C, Bruno CM, et al. Electronic cigarette: a possible substitute for cigarette dependence. Monaldi Arch Chest Dis. 2013;79:12–19.
2. Farsalinos KE, Romagna G, Tsiapras D, et al. Characteristics, perceived side effects and benefits of electronic cigarette use: a worldwide survey of more than 19,000 consumers. Int J Environ Res Public Health. 2014;11:4356–4373.
3. Biener L, Hargraves JL. A longitudinal study of electronic cigarette use among a population-based sample of adult smokers: association with smoking cessation and motivation to quit. Nicotine Tob Res. 2015;17:127–133.
4. Farsalinos KE, Polosa R. Safety evaluation and risk assessment of electronic cigarettes as tobacco cigarette substitutes: a systematic review. Ther Adv Drug Saf. 2014;5:67–86.
5. Marco E, Grimalt JO. A rapid method for the chromatographic analysis of volatile organic compounds in exhaled breath of tobacco cigarette and electronic cigarette smokers. J Chromatogr A. 2015;1410:51–59.
6. Callahan-Lyon P. Electronic cigarettes: human health effects. Tob Control. 2014;23(suppl 2):ii36–ii40.

7. Cheng T. Chemical evaluation of electronic cigarettes. Tob Control. 2014;23(Suppl 2):i11–i17.

8. Goniewicz ML, Knysak J, Gawron M, et al. Levels of selected carcinogens and toxicants in vapour from electronic cigarettes. Tob Control. 2014;23(2):133–139.

9. Margham J, McAdam K, Forster M, et al. Chemical composition of aerosol from an e-cigarette: a quantitative comparison with cigarette smoke. Chem Res Toxicol. 2016 Oct 17;29(10):1662–1678.

10. Rawlinson C, Martin S, Frosina J, et al. Chemical characterisation of aerosols emitted by electronic cigarettes using thermal desorption-gas chromatography-time of flight mass spectrometry. J Chromatogr A. 2017May12;1497:144–154.

11. Rodgman A, Perfetti TA. The chemical components of tobacco and tobacco smoke. 2nd ed. Boca Raton (FL): CRC Press;; 2013.

12. Royal College of Physicians. Nicotine without smoke. Tobacco harm reduction: report of the tobacco advisory group of the royal college of physicians. London: Royal College of Physicians; 2016.

13. McNeill A, Brose LS, Calder R, et al. E-cigarettes: an evidence update. A report commissioned by Public Health England. London: Public Health England; 2015.

14. Nutt DJ, Phillips LD, Balfour D, et al. Estimating the harms of nicotine-containing products using the MCDA approach. Eur Addict Res. 2014;20:218–225.

15. National Academies of Sciences, Engineering, and Medicine. Public health consequences of e-cigarettes. Washington, DC: The National Acad- emies Press; 2018. doi:10.17226/24952.

16. Sosnowski TR, Kramek-Romanowska K. Predicted deposition of e-cigarette aerosol in the human lungs. J Aerosol Med Pulm Drug Deliv. 2016;29(3):299–309.

17. Mikheev VB, Brinkman MC, Granville CA, et al. Real-time measurement of electronic cigarette aerosol size distribution and metals content analysis. Nicotine Tob Res. 2016;18(9):1895–1902.

18. Pichelstorfer L, Hofmann W, Winkler-Heil R, et al. Simulation of aerosol dynamics and deposition of combustible and electronic cigarette aerosols in the human respiratory tract. J Aerosol Sci. 2016;99:125–132.

19. Generally Recognized as Safe (GRAS). [Internet]. Washington, DC: U.S. Food & Drug Administration; 2017. Available from: https://www.fda.gov/food/ingredientspackaginglabeling/gras/

20. Cotta KI, Stephen CD, Mohammad NU. A review on the safety of inhalation of propylene glycol in E-cigarettes. Glob J Pharmaceu Sci. 2017;2(2):555584. Available at: https://juniperpublishers.com/gjpps/pdf/GJPPS.MS.ID.555584.pdf.

21. Wieslander G, Norback D, Lindgren T. Experimental exposure to propylene glycol mist in aviation emergency training: acute ocular and respiratory effects. Occup Environ Med. 2001;58:649–655.

22. Polosa R, Caponnetto P, Morjaria JB, et al. Effect of an electronic nicotine delivery device (e-cigarette) on smoking cessation and reduction: a prospective pilot study. BMC Public Health. 2011;11:786.

23. Caponnetto P, Campagna D, Cibella F, et al. EffiCiency and Safety of an eLectronic cigAreTte (ECLAT) as tobacco cigarettes substitute: a prospective 12-month randomized control design study. PLoS One. 2013;8:e66317.

24. Hannuksela M, Förström L. Reactions to peroral propylene glycol. Contact Dermat. 1978;4:41–45.

25. Hua M, Alfi M, Talbot P. Health-related effects reported by electronic cigarette users in online forums. J Med Internet Res. 2013;15(4):e59.

26. Vardavas C, Anagnostopoulos N, Kougias M, et al. Short-term pulmonary effects of using an electronic cigarette: impact on respiratory flow resistance, impedance, and exhaled nitric oxide. Chest. 2012;141:1400–1406.

27. Lappas AS, Tzortzi AS, Konstantinidi EM, et al. Short-term respiratory effects of e-cigarettes in healthy individuals and smokers with asthma. Respirology. 2018 Mar;23(3):291–297..

28. Staudt MR, Salit J, Kaner RJ, et al. Altered lung biology of healthy never smokers following acute inhalation of E-cigarettes. Respir Res. 2018 May 14;19(1):78..

29. Flouris A, Chorti M, Poulianiti K, et al. Acute impact of active and passive electronic cigarette smoking on serum cotinine and lung function. Inhal Toxicol. 2013;25:91–101.

30. Ferrari M, Zanasi A, Nardi E, et al. Short-term effects of a nicotine-free e-cigarette compared to a traditional cigarette in smokers and non-smokers. BMC Pulm Med. 2015;15:120.

31. MÈ B, Henry C, Bossé Y, et al. Acute effects of nicotine-free and flavour-free electronic cigarette use on lung functions in healthy and asthmatic individuals. Respir Res. 2017 Feb 10;18(1):33..

32. D'Ruiz CD, O'Connell G, Graff DW, et al. Measurement of cardiovascular and pulmonary function endpoints and other physiological effects following partial or complete substitution of cigarettes with electronic cigarettes in adult smokers. Regul Toxicol Pharmacol. 2017;87:36–53.

33. Cravo AS, Bush J, Sharma G, et al. A randomised, parallel group study to evaluate the safety profile of an electronic vapour product over 12 weeks. Regul Toxicol Pharmacol. 2016 Nov 15;81(Suppl 1):S1–S14..

34. Cibella F, Campagna D, Caponnetto P, et al. Lung function and respiratory symptoms in a randomized smoking cessation trial of electronic cigarettes. Clin Sci (Lond). 2016;130(21):1929–1937.

35. Campagna D, Cibella F, Caponnetto P, et al. Changes in breathomics from a 1-year randomized smoking cessation trial of electronic cigarettes. Eur J Clin Invest. 2016;46(8):698–706.

36. Polosa R, Cibella F, Caponnetto P, et al. Health impact of E-cigarettes: a prospective 3.5-year study of regular daily users who have never smoked. Sci Rep. 2017 Nov 17;7(1):13825..

37. Morjaria JB, Malerba M, Polosa R. Biologic and pharmacologic therapies in clinical development for the inflammatory response in COPD. Drug Discov Today. 2010;15(9–10):396–405.

38. Fletcher C, Peto R. The natural history of chronic airflow obstruction. Br Med J. 1977;1(6077):1645–1648.

39. Hersh CP, DeMeo DL, Al-Ansari E, et al. Predictors of survival in severe, early onset COPD. Chest. 2004;126:1443–1451.

40. Kanner RE, Connett JE, Williams DE, et al. Effects of randomized assignment to a smoking cessation intervention and changes in smoking habits on respiratory symptoms in smokers with early chronic obstructive pulmonary disease: the Lung Health Study. Am J Med. 1999;106:410–416.

41. Polosa R, Morjaria JB, Prosperini U, et al. Health effects in COPD smokers who switch to electronic cigarettes: a retrospective-prospective 3-year follow-up. Int J Chron Obstruct Pulmon Dis. 2018Aug22;13:2533–2542.

42. Arcavi L, Benowitz NL. Cigarette smoking and infection. Arch Internal Med. 2004;164:2206–2216.

43. Almirall J, Bolíbar I, Serra-Prat M, et al. Community-Acquired Pneumonia in Catalan Countries (PACAP) Study Group. New evidence of risk factors for community-acquired pneumonia: a population-based study. Eur Respir J. 2008;31:1274–1284.

44. Huttunen R, Heikkinen T, Syrjanen J. Smoking and the outcome of infection. J Intern Med. 2011;269:258–269.

45. Campagna D, Amaradio MD, Sands MF, et al. Respiratory infections and pneumonia: potential benefits of switching from smoking to vaping. Pneumonia. 2016;8:4.

46. Puck TT, Robertson OH, Lemon HM. The bactericidal action of propylene glycol vapor on microorganisms suspended in air: ii. the influence of various factors on the activity of the vapor. J Exp Med. 1943;78:387–406.

47. Robertson OH, Loosli CG, Puck TT, et al. The protection of mice against infection with air-borne influenza virus by means of propylene glycol vapor. Science. 1941;94:612–613.

48. Fuochi V, Caruso M, Emma R, et al. Electronic cigarette liquids inhibit pathogenic bacteria growth in vitro. J Antimicrob Chemother. submitted for publication to Respir Res.

49. McConnell R, Barrington-Trimis JL, Wang K, et al. Electronic cigarette use and respiratory symptoms in adolescents. Am J Respir Crit Care Med. 2017;195(8):1043–1049.

50. Choi K, Bernat D. E-cigarette use among Florida youth with and without asthma. Am J Prev Med. 2016;51(4):446–453.