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# Consequences of the vaping epidemic on adolescents

BY MICHELLE PATTERSON, MSN, RN; PAMELA WILLIAMS-JONES, MSN, RN;  
AND TRAVIS "PETE" LEWIS, PhD, RN

**Abstract:** The prevalence of vaping has seen a dramatic increase in the last decade, especially among adolescent populations. This article discusses the background, prevalence, and associated risk factors of e-cigarettes.

**Keywords:** adolescents, e-cigarette, e-cigarette or vaping product use-associated lung injury, EVALI, smoking, vaping, vitamin E acetate

IN THE LAST DECADE, the use of e-cigarettes has increased dramatically among adolescent populations. Commonly referred to as vaping, the use of e-cigarettes has become a public health concern throughout the US. This article discusses the background, prevalence, and associated risk factors of vaping for youth.

## Background

E-cigarettes were conceptualized in 1965. The first version, an atomic atomizer, was patented in China in 2003.<sup>1</sup> By 2007, it was being marketed in the US as a healthier option than conventional cigarettes because it produced "only harmless water vapor instead secondhand smoke."<sup>1,2</sup> (See *Marketing impact*.)

Since the technology's inception, however, different e-cigarette products have been created to deliver varying levels of nicotine aerosol. The wide variety of these products

in an ever-changing market only escalates concerns related to safety, cessation effectiveness, and public health impact.<sup>2</sup> Additionally, users may alter many e-cigarette products to deliver other drugs, such as marijuana or more illicit substances.<sup>3</sup>

These products faced little regulation until May 2016, when the Deeming Rule was added under the Family Smoking Prevention and Tobacco Control Act of 2009. This granted the FDA complete authority over e-cigarettes as related to all tobacco products.<sup>4</sup> In 2018, the FDA and Surgeon General declared youth e-cigarette usage an epidemic.<sup>5</sup> Findings from the 2019 National Youth Tobacco Survey revealed high rates of e-cigarette usage among both middle and high school students, with 5 million participants having reported using e-cigarettes within the past 30 days and approximately 1 million reporting daily use.<sup>6</sup>

The vaping epidemic received further public attention in November 2019, when President Trump held a White House meeting to discuss e-cigarettes. During the meeting, representatives from the American Academy of Family Physicians (AAFP), the American Medical Association, the American Lung Association (ALA), the American Cancer Society, Parents Against Vaping e-cigarettes, the Campaign for Tobacco-Free Kids, and the Truth Initiative emphasized the need to ban flavored e-cigarettes.<sup>7</sup>

Given the rates of use, adverse effects, and lack of public knowledge, health-care professionals must act to reduce this public health crisis with a focus on adolescents. According to AAFP President Gary Leroy, “the reality is that e-cigarette flavors are aimed at young people,” and halting the epidemic of nicotine addiction must be a priority.<sup>7</sup>

### Prevalence in adolescents

Vaping among adolescents has risen sharply, both nationally and internationally. The CDC predicts that, at the current rate of use among US youth, 5.6 million individuals under age 18 will face early death due to smoking-

related illnesses.<sup>8</sup> In 2017 and 2018, repeat cross-sectional online surveys on smoking and vaping sampled individuals ages 16 to 19 in Canada, England, and the US. The results confirmed an increased prevalence of vaping in the previous 30 days, 15 days, and 7 days among Canadian and US adolescents with no changes among the English participants.<sup>9</sup>

Among US youth specifically, an estimated 27.5% of high school students and 10.5% of middle school students self-reported vaping in the previous 30 days.<sup>5</sup> This report demonstrates a marked increase from 20.8% of high school students in 2018 to 27.5% in 2019.<sup>10</sup> Among adolescent users, an estimated 72.2% of high school participants and 59.2% of middle school participants used flavored e-cigarettes.<sup>5,9</sup> In 2019, the number of high school students using tobacco products increased by approximately 38% over the course of the year, a finding that the CDC attributes to the popularity of e-cigarettes.<sup>10</sup>

Certain products use benzoic acid and nicotine salt to produce higher concentrations of nicotine than conventional e-cigarettes.<sup>5</sup> These

brands tend to be preferred among adolescents.<sup>9</sup> Exposure to high doses of nicotine may predispose adolescent users to nicotine dependence and addiction.<sup>5</sup> The rapidly growing market and high prevalence of self-reported e-cigarette users among high school and middle school students warrants close monitoring and further investigation.

### Psychosocial factors

The teen years are crucial to brain development into young adulthood, and nicotine affects the neurologic pathways that control attention and learning. Adolescents may also be at an increased risk for mood disorders and permanent problems with impulse control due to nicotine use.<sup>11</sup>

Two variables may contribute to the significant increase in adolescent use of e-cigarettes: feelings of invincibility and peer pressure. Many adolescents have the perception that the consequences of high-risk behaviors will not happen to them. This illusion of invincibility correlates with a propensity for risky behaviors such as smoking and alcohol use.<sup>12</sup> The “it will never happen to me” mindset is normal in adolescents, but it can limit their ability to accurately assess situations, risks, and future consequences.<sup>13</sup> This may correlate with the consequences of other high-risk behaviors such as pregnancy, motor vehicle crashes, and sexually transmitted infections.<sup>14</sup>

Because peer acceptance is paramount, teens may modify their behaviors to fit in. This can lead to problems, especially in early and middle adolescent years.<sup>15</sup> Although school-based community programs have improved awareness of peer pressure, adolescent involvement in high-risk behavior continues to be challenging due to the peer pressure, feelings of invincibility, and neurologic and cognitive development associated with this age group.<sup>11,12,15-17</sup>

As adolescent brains are still developing, they are more susceptible to

## Marketing impact

Consumers have been bombarded with claims that e-cigarettes are healthier, cleaner, cheaper, and more convenient because they can be used anywhere.<sup>57</sup> Other marketing messages state that these products produce only a harmless water vapor, not secondhand smoke, allowing users to circumvent smoke-free policies. Strategies using celebrities in e-cigarette marketing campaigns have been in place for a decade.<sup>5</sup> Current research demonstrates celebrity endorsements of e-cigarettes in social networking sites can have a powerful effect on attitudes and e-cigarette smoking intentions.<sup>58</sup>

Widespread and comparatively unrestricted e-cigarette advertising may be one critical factor in e-cigarette usage, especially among youth. E-cigarettes have been excluded from the rules and regulations that govern marketing and advertising for cigarette and tobacco companies.<sup>57,59</sup> Specifically, TV, radio, internet, and billboard advertising have allowed these companies to reach youth as well as adults.<sup>60</sup>

Another youth-oriented marketing tactic is the use of flavoring. Flavor and taste is a common reason for e-cigarette use among adolescents and young adults, along with curiosity and the perception that e-cigarettes are safer than conventional cigarettes.<sup>1</sup> In a 2020 news release, the FDA announced an enforcement policy regarding unauthorized flavored e-cigarette cartridges that appeal to children, including mint and fruit.<sup>61</sup> Under the new policy, e-cigarette cartridge flavors other than tobacco and menthol will no longer be authorized or approved.<sup>62</sup>



addiction. Even those who vape just once are more likely to try other types of tobacco.<sup>16</sup> Like other addictive substances, nicotine activates the brain's reward pathways that reinforce certain behaviors, such as nicotine use, despite the health risks. Vaping can lead to nicotine addiction and an increased risk for abuse of other substances.<sup>11</sup>

### Potential gateway drug

Given the high levels of nicotine in e-cigarettes, they are gaining recognition as a potential gateway to combustible tobacco products and other drug use.<sup>18</sup> According to the National Institute on Drug Abuse (NIDA), early evidence suggests that e-cigarettes may serve as an introductory product for teens and preteens, who then go on to use other products such as cigarettes.<sup>11</sup> NIDA also reported that individuals who use tobacco products earlier in life are at increased risk for substance abuse.<sup>11</sup> A 2019 study found that vaping was closely linked with use of cigarettes, alcohol, marijuana, cocaine, amphetamines, inhalants, hallucinogens, ecstasy, and over-the-counter and prescription medications.<sup>18</sup>

Analysis of the 2014 national youth tobacco survey demonstrated that using both electronic and combustible tobacco is dominant among US middle and high school students.<sup>19</sup> Although this remains underexplored, a survey using cross-sectional analysis demonstrated that 3.1% of adolescents in middle and high school had tried e-cigarettes in 2011, with 1.7% having tried both and 1.5% having tried only e-cigarettes. Additionally, 1.1% identified as current e-cigarette users, with 0.5% using both electronic and combustible tobacco products and 0.6% using only e-cigarettes.<sup>20</sup>

By 2012, 6.5% of the sample had tried e-cigarettes, with 2.6% having tried both and 4.1% having tried e-cigarettes only. This time, 2.0% of participants were current e-cigarette users, with 1.0% using both and



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1.1% using only e-cigarettes. The use of e-cigarettes was linked to an increased risk of trying or regularly smoking conventional cigarettes.<sup>21</sup>

### Vaping and cannabis

Amid the growing prevalence of vaping in adolescents are increased concerns regarding teen use of e-cigarettes to inhale cannabis oil. Both nicotine and marijuana stimulate the release of dopamine in the brain.<sup>22</sup> For many adolescents, vaping has already progressed from nicotine to marijuana, with approximately 1 in 11 middle and high school students in the US reporting cannabis use via e-cigarettes.<sup>23</sup> These estimates are consistent with or higher than previous reports among US and Canadian students.<sup>23</sup>

Due to substantially increased concentrations of tetrahydrocannabinol (THC), the popularity of

vaping marijuana poses a major threat to adolescent users. THC, the psychoactive component of cannabis, can be dissolved in vegetable oil or seeped from the marijuana, allowing for higher concentrations.<sup>24,25</sup> THC content in the liquid concentrates used in e-cigarettes can range between 50% and 90% compared with just 20% in conventional marijuana cigarettes.<sup>25</sup>

### The truth about nicotine

Despite abundant literature verifying the risks associated with traditional cigarettes, evidence related to the long-term risks of e-cigarettes and e-cigarette liquids is inconclusive. However, nicotine is a component of many solutions used in e-cigarettes, and the effects of addiction are well documented and indisputable. A collection of studies has demonstrated nicotine's adverse effects on developing adolescent brains and its impact on executive functions such as working memory, attention, and decision-making.<sup>11,26</sup> This is especially relevant, considering a 2019 study that noted the nicotine quantity in some e-cigarette cartridges may be equivalent to up to 20 conventional cigarettes.<sup>27</sup>

Another 2019 study cited the harmful effects of oxidative stress associated with e-cigarettes on developing brains, potentially contributing to social maladjustments among adolescents and leading to problems with learning and academic performance, memory, aggressive or compulsive behaviors, attention, sleep quality, and depression or suicide ideation.<sup>28</sup> Chronic exposure to nicotine increases the number of neuronal nicotinic receptors, making addiction more difficult to overcome.<sup>29</sup>

Nicotine-free e-cigarette products may contain other potentially harmful chemicals as well.<sup>27</sup> For example, the FDA recently found chemicals linked to cancer, including ingredients found in antifreeze and formaldehyde, in the aerosol of higher voltage e-cigarettes from two popular brands.<sup>30</sup> According

to the ALA, acrolein, a substance used as a weed killer and found in e-cigarette aerosols, may cause irreversible lung damage.<sup>31,32</sup>

Calls to poison control centers have skyrocketed due to adverse reactions to vaping and other exposures. Nonvaping contact with the e-cigarette fluid or liquid nitrogen is hazardous and may necessitate a visit to the ED. Both pediatric and adult patients have experienced adverse reactions due to the accidental swallowing, breathing, or skin absorption of e-cigarette liquid. The death of a toddler led to the Child Nicotine Poisoning Prevention Act of 2015, which required manufacturer compliance with the special childproof packaging laws to reduce the risk of poisoning.<sup>33,34</sup>

Further, defective batteries and exploding e-cigarette devices have caused injuries. Between 2015 and 2017, more than 2,000 explosions and burn injuries related to e-cigarettes were reported.<sup>35</sup> Some of these resulted in serious injuries such as third-degree burns and the loss of teeth, eyes, and tongues. In May 2018, a head wound caused by an exploding e-cigarette was determined to be the cause of one individual's death.<sup>35</sup>

The Deeming Rule has since allowed for government oversight of e-cigarette batteries under the FDA's Center for Tobacco Products, but the agency has yet not moved forward with any regulations. Congressional action may be warranted to allow the US Consumer Product Safety Commission to improve the regulations associated with e-cigarette products.<sup>35</sup>

### **E-cigarette-associated lung injury**

In 2019, the CDC characterized e-cigarette, or vaping, product use-associated lung injury (EVALI) as an acute or subacute respiratory illness that can be severe and life-threatening and involve various diseases.<sup>36</sup> Approxi-

mately 80% of patients with EVALI are under age 35, with a range of 13 to 75.<sup>36</sup> In 2019, a teenage patient with EVALI required a bilateral lung transplant after becoming critically ill.<sup>37</sup>

According to the CDC, most patients with EVALI self-report using products that contain THC, which may play a key role in the occurrence of vaping-related illness.<sup>37</sup> As of February 2020, the CDC had confirmed 2,807 patients hospitalized with EVALI, with 68 deaths reported from all 50 states, Washington D.C., Puerto Rico, and the US Virgin Islands; this is in comparison with 2,291 cases and 48 deaths as of December 2019.<sup>38</sup>

Data from national and state reports indicate that THC-containing e-cigarette products are linked to most cases and represent a major factor in the increased rates of EVALI, especially those from informal sources such as acquaintances or online dealers.<sup>39</sup> Further analysis revealed that THC exposure included 152 different THC-containing products, the most common of which were identified as largely counterfeit.<sup>39</sup>

Vitamin E acetate is another damaging compound associated with EVALI. Illicit users sometimes add it as a thickening agent or to dilute THC to increase profits.<sup>37,40</sup> Vitamin E acetate transforms from an oil to a vapor at high temperatures, and it can be described as similar to a coating of honey that sticks to the lungs.<sup>38,41</sup> Once inhaled, it reverts to an oil state that could sicken the user.<sup>42</sup> The exact cause and mechanism of EVALI is unclear, requiring more research.

Vitamin E may be harmless when swallowed or applied to the skin, but it can damage the lungs when inhaled.<sup>43</sup> Vitamin E oil found in bootleg THC e-cigarette products is affordable, easy to purchase wholesale, and likely related to at least a portion of documented EVALIs.<sup>38,44</sup> Many patients with EVALI reported using THC-containing products, par-

ticularly counterfeit brands, which often contain vitamin E acetate.<sup>45</sup>

### **Assessment and diagnosis**

The only identifiable risk factor for EVALI is current or previous use of an e-cigarette device, but healthcare providers should consider screening for the use of e-cigarettes or related products in the last 90 days, presence of lung opacities on imaging studies, exclusion of other lung infections, evaluation for community-acquired pneumonia, and absence of a probable alternative diagnosis.<sup>36,46,47</sup>

As there are no specific markers or tests currently available, an EVALI diagnosis is based on exclusion.<sup>46</sup> Clinical presentations suggest that it is comprised of several different lung injuries. Most patients present with respiratory signs and symptoms such as shortness of breath, chest pain, and cough. Others include nausea, vomiting, fever, and weight loss.<sup>48</sup> Because the signs and symptoms may mimic other respiratory disorders such as influenza or pneumonia, it may be challenging to diagnose and treat patients.<sup>46</sup> (See *Vaping and COVID-19*.)

Researchers at the University of Rochester developed a diagnostic algorithm in conjunction with the New York State Department of Health that allows for rapid identification of patients with suspected EVALI based on their health history, clinical presentation, and chest imaging.<sup>49</sup> When evaluating adolescents with respiratory signs and symptoms, healthcare professionals should ask about the use of e-cigarettes in a confidential and nonjudgmental manner.<sup>48</sup> It is essential to obtain an accurate patient history for e-cigarette use within the last 30 days to rule out alternative diagnoses, as well as chest imaging and lab testing including a complete blood cell count and differential, blood urea nitrogen, and creatinine.<sup>48</sup> EVALI may also present concurrently with other respiratory tract infections.<sup>48</sup> Inform

parents that their child's respiratory issues could be related to vaping.<sup>50</sup>

### Management

The CDC recommends hospital admission for those with concurrent infections, particularly if they are experiencing respiratory distress, comorbidities that compromise pulmonary reserve, or decreased SpO<sub>2</sub> levels (less than 95% on room air). Certain patients may be candidates for outpatient management of EVALI if their SpO<sub>2</sub> is 95% or higher on room air and they are experiencing no respiratory distress or pulmonary comorbidities. Patients must also have dependable access to care and strong social support systems, ensuring follow-up within 48 hours of the initial evaluation. Empiric antibiotics are typically initiated in these patients to prevent community-acquired pneumonia, but those who experience worsening respiratory symptoms should seek medical care immediately.<sup>48</sup>

Providers must use caution when considering corticosteroids. This treatment has not been well studied among outpatients and may worsen respiratory infections. Other evidence-based treatment strategies include behavioral counseling to assist with e-cigarette cessation. Stress the importance of annual seasonal influenza vaccinations.<sup>48</sup>

### Prevention

The focus of prevention is public education on the dangers of vaping. The CDC strongly advises adolescents, young adults, pregnant women, and adults who do not currently use tobacco to avoid all e-cigarette products.<sup>36</sup> The agency specifically cautions against using any vaping product that contains THC, especially those acquired from family, friends, or illicit markets and pop-up shops in which there is uncertainty regarding exact ingredients.<sup>36,40</sup> Strategies to reduce vaping in teenage populations include indoor smoking restrictions,

## Vaping and COVID-19

In the midst of the COVID-19 pandemic, concern is growing regarding the relationship between vaping and the novel coronavirus. Given the increasing incidence of vaping among adolescents, it is important to understand any correlations.<sup>5,9,10</sup> Although there is currently no definitive evidence, experts believe individuals who smoke or use e-cigarette products may be at an increased risk for secondary complications from COVID-19.<sup>63</sup> Recent anecdotal evidence suggests that COVID-19 may be affecting young people because these individuals are more likely to be vaping.<sup>64</sup>

Smoking or vaping may increase the risk of a severe COVID-19 infection, and it is reasonable to conclude that there may be a connection.<sup>65,66</sup> Given the increased risk of lung injuries and death associated with vaping and the impact of COVID-19 on patient lungs, early-onset lung injury or inflammation caused by vaping may be doubly harmful to those infected with the virus.<sup>66,67</sup> Smoking and vaping result in inflamed, fragile lung tissue that is susceptible to infection, compromising the respiratory system.<sup>68</sup> According to NIDA, individuals who vape or smoke cigarettes and marijuana may be at increased risk if they contract COVID-19.<sup>63</sup>

bans on advertising aimed at children, taxes as an economic disincentive, and public education.<sup>1</sup>

Many programs are geared toward education and support for the cessation or avoidance of tobacco products. The Truth Initiative, a US non-profit tobacco control organization, is working to educate the public on e-cigarettes and engage communities by helping people quit vaping through a research-based text message program that was created with input from teens, college students, and young adults.<sup>51</sup> Funded by \$60 million in fees collected from the tobacco industry, the FDA expanded its Youth Tobacco Prevention Plan in 2018 to reach youth populations both in the classroom and on social media.<sup>52</sup> Quit Now, a nationwide free program, provides free tools, tips, and resources for smokers who want to quit.<sup>53</sup>

Additionally, recent legislation amended the Federal Food, Drug, and Cosmetic Act to raise the federal minimum age for purchasing tobacco products from age 18 to 21.<sup>54</sup> As of January, the FDA had conducted more than 1 million compliance inspections of tobacco retailers.<sup>54</sup>

### Adolescent education

Despite the increased popularity of e-cigarettes, most adolescents and young adults do not know exactly

what is in the products.<sup>55</sup> A recent survey demonstrated that 63% of youth participants did not know that nicotine is present in e-cigarettes.<sup>55</sup> This finding identified one aspect of the required public education.

Three factors affect successful adolescent education: feelings of invincibility, the influence and acceptance of peers, and limited ability to think abstractly. Information should be related to the short-term consequences such as bad breath or loss of athletic ability, rather than long-term consequences such as cancer.<sup>13</sup>

Begin by addressing the “it won’t happen to me” mindset with a “yes, it can happen to me” attitude. Establish a relationship, relate the consequences to everyday life, and share personal experiences. Create a vivid picture of the risks by demonstrating that not everyone gets away with it (for example, by involving peers who have experienced these consequences). Empower students by recognizing and building on their strengths.<sup>12</sup>

Certain strategies can be helpful when implementing a teen awareness program. These include peer interaction, peer-led groups, and a nonjudgmental attitude among educators and facilitators. Include familiar jargon and provide focused examples of the immediate effects of e-cigarette use.

## The time is now

Public education is vital. This epidemic requires input from health-care professionals, especially nurses. Nurses are uniquely positioned to combat adolescent vaping with patient education and empowerment. While this effort is important to all age groups, adolescents should be a target population. The ultimate goal is to prevent teens from trying or experimenting with e-cigarettes or to help with cessation.

Comprehensive prevention and cessation programs targeting adolescents are urgently needed. Current industry, government, and school programs have been inadequate in stopping the rapid spread of vaping among adolescents.<sup>56</sup> Nurses can offer the necessary public awareness and education to address the common myths, misconceptions, and dangers of vaping. Effective awareness programs must focus on the present. The time is now for nurses to take an active leadership role and advocate for education that will help motivate young patients to cease or resist the use of e-cigarettes. ■

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At Nicholls State University in Thibodaux, La., Michelle Patterson is an assistant professor, Pamela Williams-Jones is an associate professor, and Travis "Pete" Lewis is a professor.

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