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What the Advanced Practice Nurse in the Emergency Department Needs to Know About the Health Risks and Hazards of Electronic Cigarette Use by Youth

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Abstract
Despite the decline in traditional tobacco use among teens and young adults, the rapid increase in electronic cigarette (EC) use has filled the gap, raising concern that this will usher in a new generation of tobacco users. Although long-term effects have not been clearly established, EC use is not without risks or hazards that may be encountered by the advanced practice nurse in the emergency department (ED). The ED presents an opportune moment for health promotion and risk reduction education for patients and families, but there are also dangers to EC use that the practitioner should be aware of and prepared to manage. Nicotine, found in most EC liquids, is well known to be a neurotoxin that affects brain development in young people. It is important to inform young people and families that EC products may contain not only nicotine but also other harmful chemicals and are not just harmless water vapor. Other toxins found in EC liquids and vapors raise questions about the health impact of long-term EC use and add additional concerns for secondhand exposure for children and pregnant women. The EC is also used by youth to inhale concentrated forms of cannabis, which could be a precursor to EC use for other illicit drugs. Hazards to be prepared for in the ED are accidental ingestion of EC liquids by children and intentional overdose of concentrated liquids. Severe injuries have been reported from explosions of EC devices as well. The ED is a starting point for EC screening and education of young people and families. Advanced practice nurses must also anticipate and be prepared to handle any other untoward effects from exposures to devices and liquids. The purpose of this article is to inform and prepare advanced practice nurses with the latest information to manage these patient encounters.
Key words: advanced practice nurse, electronic cigarette, emergency department

IN THE LAST 5 YEARS, there has been a welcome significant decline in traditional tobacco use among youth. However, electronic cigarette (EC) use is rapidly increasing, with the 2011 through 2015 National Youth Tobacco Survey (NYTS) reporting that ECs have become the most commonly used tobacco delivery system in the United States (Singh, Arrazola, et al., 2016). As with traditional cigarettes (referred to as combustible cigarettes in this article), there are risks and hazards associated with EC use. These devices heat liquids that often contain nicotine and other potentially dangerous chemicals. Risks

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surrounding nicotine exposure are increased in youth during the critical period up to 25 years of age when the brain is developing abilities that control attention, learning, and susceptibility to addiction (U.S. Department of Health and Human Services [DHHS], 2016). There is also preliminary evidence that chemicals found in exhaled vapors may be harmful to others who experience second- and third-hand exposure (Goniewicz & Lee, 2015). Hazards associated with EC use include injuries related to malfunctioning EC devices, accidental nicotine ingestion by children, and intentional nicotine overdose (DHHS, 2016). The purpose of this article is to inform advanced practice nurses (APNs) working in the emergency department (ED) about the risks and hazards associated with EC use and the implications for screening, assessment, education, and treatment of young patients in the ED. The practice of EC use is relatively new and is rapidly gaining popularity in this population. It is important for APNs to stay up to date on the newest trends and the potential for adverse health effects.

EPIDEMIOLOGY

The 2011–2015 NYTS showed a significant increase in EC use, with a rate of 16% among high school students and 5.3% among middle school students. Combustible cigarette use prevalence has declined in this population, but with the increase in EC use, the overall tobacco product use by high school students in 2015 remained critically high at 25.3%. Also concerning is the rise in middle school youth EC use, increasing from 3.9% in 2010 to 5.3% in 2015 (Singh, Arrazola, et al., 2016). The minimum age of reported initiation of EC use is 7 years, with the peak at 17 years of age (Chen, Yu, & Wang, 2017). The predominant EC user is non-Hispanic White (17.2%) or Hispanic (16.4%) males (Singh, Arrazola, et al., 2016). Like cigarette smokers, EC users compared with nonsmokers are more likely to use alcohol, marijuana, other illicit drugs, as well as nonmedical use of prescription drugs (Demissie, Jones, Clayton, & King, 2017). The rapidly increasing use of EC products by youth is a cause for concern from both acute illness or injury and health promotion perspectives. Lack of knowledge by the APN about the prevalence of this problem may limit the effectiveness of the patient encounter and represent a lost opportunity for patient education.

ELECTRONIC CIGARETTE PRODUCTS

The basic design of EC devices includes a rechargeable lithium ion battery-powered heating element that vaporizes liquid contained in a reservoir and a mouthpiece that allows vapor to be inhaled. Most EC products are referred to as electronic cigarettes, e-cigs, electronic cigars, e-hookahs, vape pens, tank systems, and "mods" or modifiable "tanks." The disposable EC has a limited number of puffs and varying doses of nicotine. The reusable EC requires a cartridge that is filled with various e-liquids or "juice" that may be refillable. These e-liquids may include propylene glycol, glycerol, water, nicotine, flavoring, and other chemicals (see Figure 1). The practice of smoking an EC is called "vaping" (DHHS, 2016; Drummond & Upson, 2014).

Figure 1. Electronic cigarette components. From "*The facts on the FDA's New Tobacco Rule*," by Food and Drug Administration, 2017. Retrieved from https://www.fda.gov/ForConsumers/ConsumerUpdates/ucm506676.htm the Food and Drug Administration. Used with permission.

A practice called "dripping" is another mode of use in which the e-liquid is dripped onto high temperature atomizer coils and immediately inhaled (Krishnan-Sarin et al., 2016). Most adolescents use refillable or rechargeable EC products (53.4%) versus disposable, and 32.5% have used these devices to inhale substances other than nicotine. Products are readily available for purchase in retail shops and online but are most commonly obtained by adolescents from friends and family (Singh, Kennedy, et al., 2016).

ELECTRONIC CIGARETTE REGULATION/POLICY

Most EC products are manufactured by the tobacco industry, and much of the marketing appears to be targeted at adolescents and young people. There are candy flavors added to e-liquids, and advertising depicts young people using the products. Vapors that are highly visible provide a desirable image and encourage use. Recently, the Food and Drug Administration (FDA) developed new regulations to prohibit the distribution of EC products to adolescents younger than 18 years and to require health warnings on labels. When implemented, the new EC product standard rules will allow the FDA to review ingredients, product design, health risks, and the products' appeal to youth (FDA, 2017). Although some progress has been made with local policies to discourage public use of ECs and the FDA ban on EC purchase by adolescents, most youth find the products easy to obtain from friends, family, or through Internet purchasing. Often this is the result of faulty perceptions that the products are harmless or safer than combustible cigarettes. Many, including adults, believe that the e-liquids contain only water and flavors (DHHS, 2016). This misinformation may facilitate youth access to ECs and prevent children from being protected from accidentally ingesting e-liquids.

WHY ARE YOUTH ATTRACTED TO ELECTRONIC CIGARETTES?

Why do adolescents use EC products? Some indications are that it is the "cool factor," curiosity, taste of flavors, ability to do "smoke tricks" with the exhaled vapors, means to use cannabis undetected, or a way to join in with friends or family. Some believe ECs are safer than combustible cigarettes or even harmless. Adolescents who smoke combustible cigarettes may believe that EC use is healthier and will help them quit smoking. There is currently no evidence that supports use of ECs as a safe alternative for smoking cessation despite public opinion in favor of this (Dutra & Glantz, 2014). In a Connecticut study of young cigarette smokers and nonsmokers, the top three reasons for EC experimentation were curiosity (54.4%), availability of appealing flavors (43.8%), and a friend's influence (31.6%). Compared with nonsmokers, young combustible cigarette smokers are more likely to use an EC because it can be used anywhere without restriction. Current combustible cigarette smokers also report that ECs are cheaper, less harsh, smell better, more convenient, and easily hidden when compared with traditional cigarettes (Kong, Morean, Cavallo, Camenga, & Krishnan-Sarin, 2015).

ASSOCIATED RISKS

In most cases, ECs contain the same chemical, nicotine, that is found in traditional tobacco tar products. Nicotine is taken from the tobacco plant and, when inhaled, works on the brain to promote addiction. This is particularly true when used by young people whose developing brains are more vulnerable to the neurotoxic effects of nicotine (DHHS, 2016). The EC may contain higher levels of nicotine than is found in combustible cigarettes, as that level is not yet controlled by FDA regulations (FDA, 2017). Heating the e-liquid to high temperatures increases released nicotine levels and potentiates the effects. Ongoing research raises concerns that the use of EC products containing nicotine may lead adolescents to transition to combustible tobacco products and thus lead to a lifetime of smoking. A longitudinal study of Los Angeles high school students who had ever used ECs were reported

to be more likely to start using combustible cigarettes than students who never used ECs at both the 6-month (30.7% vs. 8.1%) and 1-year (25.2% vs. 9.3%) follow-ups (Leventhal et al., 2015). These and other similar findings have led many to believe that EC use among adolescents may lead to a new generation of combustible tobacco users (Dutra & Glantz, 2014).

Nicotine is not the only chemical in e-liquids that may have detrimental health consequences when inhaled. The e-liquids used in disposable and refillable ECs contain other chemicals that are often not listed on labels and are not regulated. These chemicals are predominately propylene glycol, vegetable glycerin, other toxicants that, when heated, convert to volatile aldehydes including formaldehyde. Volatile aldehydes are known to cause lung disease in combustible cigarette smokers. Heating these e-liquids to higher temperatures, such as in the popular practice of "dripping," increases the yield of nicotine and the formation of formaldehyde, acetone, and acetaldehyde at amounts comparable or higher than combustible cigarettes (Talih, Balhas, Salman, Karaoghlanian, & Shihadeh, 2016). A survey of 1,080 Connecticut high school students found that 26.1% used e-liquids for "dripping." These students reported that some of the reasons for this practice included the desire for thicker clouds of vapor, better tasting flavors, and a stronger "throat hit." The "throat hit" strength is a sensation achieved by increasing the level of nicotine inhaled (Krishnan-Sarin et al., 2017). Added flavorants also may include a harmful chemical called diacetyl, which has been found to cause bronchiolitis obliterans when inhaled (DHHS, 2016). It is not known what the long-term effects of EC use may be, and research is ongoing regarding the effects these toxic chemicals may have on the body when inhaled from an EC.

In addition to products commonly found in e-liquids, youth are also using ECs to vape cannabis. A Connecticut study of high school students found that 18% of those having ever used ECs reported using them for this purpose. The forms of cannabis used in these devices include highly concentrated hash oil, wax plugs containing tetrahydrocannabinol (THC), and dried cannabis leaves. The highly concentrated forms, when exposed to high temperatures with vaporization, release higher doses of THC than combustible cannabis. The adolescent brain is vulnerable to the chemical effects of THC, making young people more likely to become dependent. The EC devices also facilitate cannabis use by allowing the act to be easily hidden, as the vapor odor is not as pungent as combustible cannabis (Morean, Kong, Comenga, Cavallo, & Krishnan-Sarin, 2015). Concentrated forms of cannabis are now more accessible to young people because of Internet availability for the purposes of vaping. Other illicit drugs and dangerous substances could potentially be added to e-liquids for use with an EC device.

Infants, children, and pregnant women are especially vulnerable to the effects of second- and thirdhand exposure to nicotine and possibly other chemicals exhaled with EC use. Because many believe this exhaled vapor contains only water, they often vape indoors, inside vehicles, and in public places where children and pregnant women may be present. Second- and thirdhand exposure to nicotine is recognized as being harmful to the unborn fetus and children (American Academy of Pediatrics [AAP], 2015). Although little is currently known, the additional chemicals found in EC vapors may be harmful as well. These vapors contain carbonyl compounds that are known to be toxins and carcinogens. These toxins are released at greater amounts with higher vaporizing temperatures (Kosmider et al., 2014, Talih et al., 2016). Chemicals released with EC use are not only found in the air after vapors are exhaled but also remain on surfaces, food, and skin and in dust contributing to thirdhand exposure when touched, ingested, or inhaled (Goniewicz & Lee, 2015).

ASSOCIATED HAZARDS

Although still rare, explosions and burns resulting from EC use have been reported in

EDs in increasing numbers. It is speculated that this is due to poorly manufactured EC devices purchased from overseas Internet sites. Most injuries have been the result of lithium ion battery overheating while being charged. This malfunction may result in an explosion of smoke, flames, and a rapid ejection of the battery and other parts of the EC through the end of the cylinder. This explosion has been described as a "flaming rocket." Rare instances have been reported of spontaneous explosions occurring while the EC was in a person's mouth, resulting in facial injuries (U.S. Fire Administration [USFA], 2014).

Poison Control Centers received 4,128 calls regarding EC product exposure in children younger than 6 years between 2012 and 2015. Most exposures were through ingestion of e-liquid containing nicotine (95.5%), and 44.8% of the time, the EC product was stored within sight of the child. Most exposed children (79.6%) were younger than 2 years (Kamboj, Spiller, Casavant, Chounthirath, & Smith, 2016). Lack of public education regarding the dangerous contents of EC products, lack of child-resistant packing, no warning labels, and attractive flavors have put children in danger of accidentally ingesting e-liquids (AAP, 2015). Acute nicotine toxicity can be mild and include symptoms of fine tremor, nausea, tachycardia, and hypertension that usually resolve within 12 hr (see Table 1). Severe nicotine toxicity can develop rapidly after ingestion, with symptoms of increased salivation, vomiting, and diaphoresis within 1 hr of exposure. This is followed in 1–4 hr by hypotension, bradycardia, lethargy, and respiratory failure. Mild gastrointestinal effects in a child can occur with doses as low as 1 mg, with a fatal dose considered to be 1 mg/kg (1 mg/2.2 lb). Many e-liquids contain as much as or more than 20 mg/ml, which would be lethal if a 20-kg (40-lb) child ingested 1 ml (Cameron et al., 2014, Howard & Muller, 2016). A child exposed to nicotine from an EC has 2.6 times higher odds of a severe medical outcome than children exposed to combustible cigarettes (Kamboj et al., 2016).

Table 1. Clinical effects associated with e-cigarette nicotine exposure in children younger than 6 years

Cardiovascular
• Tachycardia
• Hypotension
Dermal
• Pallor
• Erythema/flushed
• Skin irritation/pain
Gastrointestinal
• Vomiting
• Nausea
• Oral irritation
• Abdominal pain
• Diarrhea
Neurologic
• Drowsiness/lethargy
• Agitation/irritable
• Dizziness
• Ataxia
• Tremor
• Confusion
• Seizure
• Coma
Ocular
• Irritation/pain
• Red eye/conjunctivitis
Respiratory
• Cough/choking
• Cyanosis
• Respiratory depression
• Respiratory arrest

Note. National Poison Data System 2012–2015. Table created with information from (Kamboj et al., 2016).

Accidental overdose by ingestion of e-liquids containing nicotine is on the rise in children, as more households have these products accessible and often not stored properly.

Although rare, intentional overdose of concentrated nicotine liquid has also been reported. Replacement e-liquid nicotine products can contain concentrations up to 100 mg/ml. The fatal dose of ingested nicotine for an adult is estimated to be 30–60 mg (Chen, Bright, Trivedi, & Valento, 2015). These incidences may be on the rise with the increased availability of e-liquids.

IMPLICATIONS FOR THE APN IN THE EMERGENCY DEPARTMENT

The APN role in the ED is not only to diagnose and treat but also to educate patients and families about preventive and health promotion. The Surgeon General's call to action for health care providers is to provide information about the dangers of EC use (DHHS, 2016). The goal is to educate young patients and their parents regarding the dangers, with the aim of limiting or eliminating the potential for adverse effects from EC use on the health of youth now and to prevent them from becoming lifelong smokers or illicit drug users in the future. This process begins with screening young patients for EC use when obtaining the mandated smoking status (Centers for Medicare & Medicaid Services, 2014). Although continued research is needed to provide definitive knowledge about the long-term effects of EC use, we know enough to advise patients and families about the potential health risks of using ECs in the adolescent years. As stated earlier, often young people get ECs from family members, so educating the entire family on this issue may be more likely to have an impact on EC use in young people (see Table 2).

Many reported EC-associated injuries have been minor burns resulting from fires that have spread from the overheated lithium ion battery to flammable objects nearby (USFA, 2014). However, there have been reports of more severe injuries from spontaneous battery explosions while the EC device was in the mouth, hand, or pant pocket that resulted in full- and partial-thickness burns. The primary concerns with these injuries are airway compromise from facial edema and burns, circumferential extremity burns, and eye injuries. Airway stabilization is the priority for these ED patients. Debridement, excision, and grafts were found to be necessary in many of the severe burns documented as having resulted from EC explosions (Treitl, Solomon, Davare, Sanchez, & Kiffin, 2017). Recommendations to prevent injuries are to use the charger provided by the manufacturer, avoid exposure of the device to heat, and stay away from oxygen sources when using an EC. However, these safety measures will not prevent injuries that occur during use. Electronic cigarettes are not regulated devices, so safety cannot be ensured, which has prompted many health care providers to recommend against the products entirely to lessen this risk of injury (USFA, 2014).

Ingestion of a nicotine-containing e-liquid puts a child at great risk for toxicity or fatality. Nicotine concentrations in e-liquids are not standardized, which presents a challenge when trying to base treatment on the amount of nicotine ingested (Cameron et al., 2014). After stabilization of a child who has ingested an e-liquid, the ED management should be guided by expert recommendations from a Poison Control Center based on the type of product and amount ingested. In most cases of mild toxicity, treatment involves support and observation for 4–6 hr with cardiac monitoring. The mild clinical effects usually last less than 2 hr, with the most common symptom being vomiting. Any potential dermal exposure should be washed with soap and water (Howard & Muller, 2016; Kamboj et al., 2016). One case was reported of an accidental overdose of nicotine-containing e-liquid that was stored in an empty children's ibuprofen bottle and then inadvertently administered to a 6-year-old child at a nicotine dose determined to be 703 mg. This child survived after receiving ED care within 30 min for severe toxicity symptoms. Supportive care included sedation, paralytic agent use, intubation, and administration of activated charcoal, followed by observation overnight (Noble, Longstreet, Hendrickson, & Gerona, 2017). Education is essential to raise parental awareness of the dangers e-liquids pose to children and the need to keep these products properly stored out of reach.

It is important for the APN in the ED to stay abreast of the most current research and guidelines regarding EC use, as the information is quickly evolving. New types of EC devices and e-liquids are becoming available, with each presenting a new challenge. There is concern in the health care community

Table 2. Tips on assessment and education of youth and parents about EC use for the emergency department advanced practice nurse

Youth	Screen all youth for EC use when asking about smoking status.
	Ask what products they use in the device (nicotine, flavors, marijuana).
	Advise that ECs contain dangerous chemicals that can harm the body. Most contain nicotine that affects brain development, they are addicting, and they may lead to cigarette and drug use.
	Advise that secondhand smoke from EC use can harm others, especially children and pregnant women.
	Advise that smoking and EC use during pregnancy may harm the fetus.
	Do not recommend EC use as an aid to quit smoking traditional cigarettes.
	Encourage youth to educate friends and family about ECs.
	Caution that EC devices may cause fires, burns, or other injuries.
Parents	Screen for EC and cigarette use in the family. Strongly advise to stop or avoid smoking or vaping around youth.
	Advise that most ECs contain nicotine, which is harmful to the developing brain of youth and may cause addiction that could lead to later cigarette or drug use.
	Recommend that parents strongly advise youth not to smoke cigarettes or vape ECs. Monitor this behavior with youth and their friends.
	Recommend modeling behavior of not smoking ECs or traditional cigarettes.
	Advise that drugs such as marijuana can be vaped in EC devices and are less detectable.
	Do not allow anyone to vape around youth or pregnant women, as they are especially vulnerable to secondhand smoke.
	EC device batteries may overheat if improperly charged, causing fires or injury; if an adult uses a device, charge with a manufacturer-provided charger.
	If an adult keeps EC liquids in the house, recommend that all products be securely stored away from children to prevent accidental ingestion.
	Monitor Internet use by youth to prevent online purchase of EC products, including marijuana and other drugs.
	Do not keep EC refill liquids assessable to youth who are at risk for suicide attempt.

Note. EC = electronic cigarette. From U.S. Department of Health and Human Services, 2016.

that EC use may create unforeseen health problems in the future. The potential use of an EC device to inhale illicit drugs is a major consideration when caring for young people. Community involvement by APNs can include promoting policies to regulate sale of EC products to youth and improve safety in labeling and packaging, as well as providing public education about hazards associated with these products. Education about risks and hazards is a key contribution by the APN when discussing EC use with young patient and their parents. Until research yields further information and efforts to regulate ECs are successful, it is important for the APN in the ED to have a heightened awareness of the potential for adverse events and poor health outcomes associated with ECs and young people.

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