Vaping: Anesthesia Considerations for Patients Using Electronic Cigarettes

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Anesthetists are generally familiar with the perioperative implications of patients' cigarette smoking. Electronic cigarettes are, however, a relatively newly popular phenomenon among adolescents and young adults. There is a generalized lack of knowledge among healthcare providers regarding the overall health effects of electronic cigarettes, which often are advertised as a harmless smoking-cessation tool. US health protection agencies have reported that electronic cigarettes contain cytotoxic compounds and harmful byproducts such as nicotine, heavy metals, propylene glycol, diacetyl, and other impurities. The current literature suggests that components of these devices (the liquid and heating element) produce chemicals that can cause acute and chronic multiorgan toxicities. On a cellular level, the pulmonary, cardiovascular, immunologic, and pharmacologic effects of electronic cigarettes are most noteworthy. The purpose of this article is to inform anesthesia providers regarding the pathophysiologic effects and anesthetic implications of electronic cigarette use.

Keywords: Anesthesia considerations, cytotoxic, electronic cigarettes, health effects, vaping.

Despite being advertised as an effective alternative to traditional cigarettes, electronic cigarettes (EC) contain nicotine and other harmful byproducts that may greatly increase the risk of complications during general anesthesia. A descriptive pilot study conducted at the Ohio State University used survey instruments to measure e-cigarette knowledge, perceptions, and awareness among healthcare providers (ie, physicians, practitioners, nurses, and respiratory therapists).[1] The study researchers concluded that there is indeed a gap in knowledge and misperceptions regarding the utility and health effects of EC. This conclusion warrants further investigation and education regarding these new products among anesthesia providers.

Electronic cigarettes, also known as electronic nicotine delivery system, are devices that produce an aerosol, or vapor, by heating a liquid that contains a desired solvent such as nicotine.[2] The primary components of EC are a plastic tube with an electronic heating element, a liquid cartridge, and a removable battery. The powered battery uses the heating element to vaporize the liquid into an aerosol, which the user (also known as vaper) then inhales[2] (Figure). The liquid, the electrical characteristic of the heating element, and the temperature reached determine the composition of the aerosol that is generated. The primary ingredients found in the liquid e-cigarette cartridges include nicotine (0-24 mg), propylene glycol, and glycerin for flavoring.[3] Other constituents of liquids and aerosols that are traceable in e-cigarettes include acetone, formaldehyde, and acetaldehyde.[3] (Refer to Table 1 for a complete list of constituents in EC.) The heat-induced degradation compounds produced from the liquid in EC show traces of heavy metals, tobacco-specific *N*-nitrosamines, and diacetyl.[4] This article identifies the health effects of these compounds and the potential anesthetic implications.

Trends and Warnings

The deleterious health effects of traditional smoking have been thoroughly studied and reported. Electronic cigarettes entered the US market in 2007 to reduce the use of traditional smoking and were primarily advertised as safe and effective.[5] Although retailers claim that EC are an effective smoking-cessation tool, a recent study by the Centers for Disease Control and Prevention (CDC) found that individuals using e-cigarettes for cessation purposes do not stop smoking cigarettes; instead, they continue to use both products.[6] Furthermore, recent studies have demonstrated that EC are not as harmless as initially presented and can also lead to adverse health effects. In August 2018, the CDC updated its warnings against e-cigarettes, pointing out the addictive and toxic effects of nicotine as well as the hazards of other chemicals contained in EC to the lungs and other organ systems.[7] Table 2 lists these specific concerns.

Of interest among the anesthesia community is the increased use of these devices in pediatric populations. The liquid that is atomized in EC (called e-liquid) is more appealing to the younger population because it may be flavored (and have a fragrance), including mint, chocolate, coffee, and various fruits.[5] The CDC has reported that there is an increase in the use of e-cigarettes among both

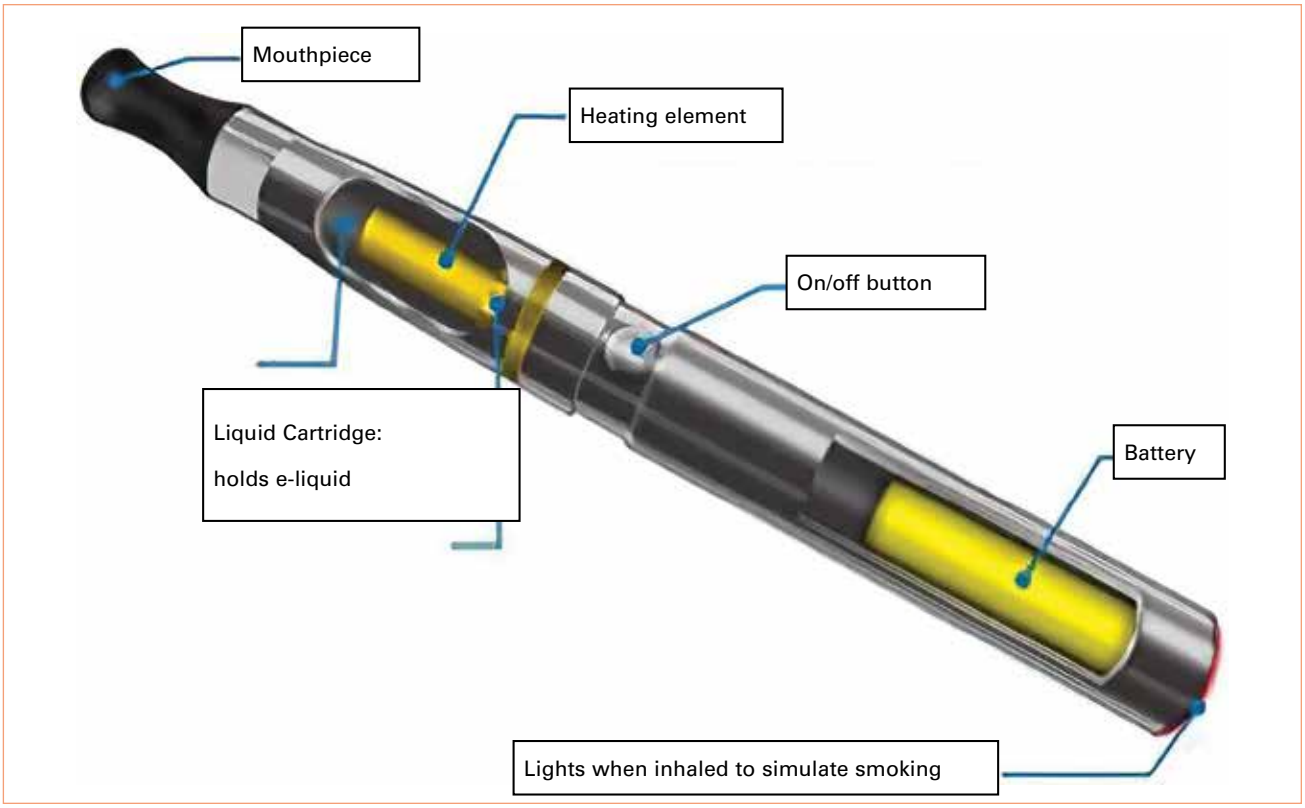

Figure. Structure of an Electronic Cigarette
Electronic cigarettes are made of a plastic tube, an electronic heating element, a liquid cartridge, and a battery. (Modified from Federal Emergency Management Agency, 2014.)

Category of constituents	Liquid	Aerosol
Listed ingredients	Glycerol	Glycerol
	Propylene glycol	Propylene glycol
	Nicotine	Nicotine
Other detectable compounds	Acetone	Acetaldehyde
	Acrolein	Acetone
	1,3-Butadiene	Acrolein
	Cyclohexane	Formaldehyde
	Diethylene glycol	*N'*-nitrosonornicotine (NNN)
	Ethylene glycol	Metals (cadmium, lead, nickel tin, copper)
	Ethanol	Toluene
	Formaldehyde	
	Tobacco alkaloids	

Table 1. Constituents of Liquids and Aerosols in E-Cigarettes
(Modified from Dinakar and O'Connor.[3])

US middle and high school students, and the proportion of young adults (18-24 years) who are current EC users exceeds that of older adults (> 25 years).[5] According to the CDC, nicotine exposure can harm adolescent brain development (which continues into the early to mid-20s) and is associated with the use of other tobacco products, including cigarettes.[6] In 2016, the US Food and Drug Administration (FDA) issued a final claim that the Tobacco Control Act provides the FDA the authority to regulate smokeless tobacco including e-cigarettes. Since the new adoption of an FDA ruling regulating EC, a person must be 18 years or older to purchase any product of this type.

The organization reported that by doing so, it hopes to reduce death and disease due to tobacco products popular among children, especially e-cigarettes.[7] The number of calls to poison control centers and visits to emergency departments related to e-liquid poisoning has significant-

Potential harm	Warning
Addiction	• Most e-cigarettes contain nicotine: the addictive drug in regular cigarettes, cigars, and other tobacco products. • Use of nicotine in adolescence may increase the risk of future addiction to other drugs.
Brain injury	• Nicotine can harm the developing adolescent brain. The brain keeps developing until about age 25 years. Use of nicotine in adolescence can harm the parts of the brain that control attention, learning, mood, and impulse control. • Nicotine also changes the way that *synapses* form, which are the learned, stronger connections built between brain cells each time a person creates a new memory or learns a new skill. Young people's brains build synapses faster than do adult brains.
Unintended bodily injury	• Defective batteries in e-cigarettes have caused explosions and fires, some resulting in serious injuries. • Children and adults have been poisoned by swallowing, breathing, or absorbing e-cigarette liquid through their eyes or skin.
Long-term health effects	• Scientists are still learning about the long-term health effects of e-cigarettes. • Some ingredients in e-cigarettes could be harmful to the lungs in the long term. For example, some e-cigarette flavorings may be safe to eat but not to inhale because the gut can process more substances than the lungs.

Table 2. Warnings About E-Cigarettes From Centers for Disease Control and Prevention[6]

ly increased because of the continuing rise in popularity of e-cigarettes.[7] According to a CDC study, the number of calls to poison centers involving e-cigarette liquids containing nicotine rose from 1 per month in September 2010 to 215 per month in February 2014.[8] The report also indicates that if EC use continues to rise at this rate, EC-related nicotine poisoning will also increase rapidly. Anesthetists may be called to the emergency department to intubate and manage patients in a state of acute nicotine intoxication. According to the FDA, severe harm can result in small children from exposure or ingestion of e-liquids, including seizures, coma, respiratory arrest, and even death.[7] The FDA banned flavored liquid used in EC to combat these recent trends, increased the minimum purchasing age to 18 years, and is preventing misleading information set forth by tobacco product manufacturers. Knowledge regarding the chemicals found in EC is beneficial to anesthesia providers given the warnings and well-documented data supporting their negative health effects (pulmonary and cardiac toxicity).

Health Effects of Electronic Cigarette Smoking

Refer to Table 3 for a summary of EC chemicals and their health effects. See Table 4 for pathophysiologic changes related to EC use.

• ***Pulmonary Effects.*** There is a growing body of evidence from in vitro, animal, and human studies indicating that e-cigarette use may cause substantial pulmonary toxicity. Electronic cigarettes affect multiple regions and functions of the respiratory system, including altering airflow, increasing oxidative stress, interfering with lung development, and impairing host defense against bacterial and viral pathogens.[9] Results of a study conducted by Garcia-Arcos et al[10] revealed that long-term EC exposure in mice induced features of chronic obstructive pulmonary disease (COPD), indicating that inhalation of nicotine-containing e-cigarettes increases airway hyperreactivity, distal airspace enlargement, mucin production, and cytokine and protease expression. Since airway epithelial cells are the primary target for any inhaled environmental agents, these agents can cause a wide range of respiratory problems such as airway inflammation and increased incidence and severity of respiratory tract viral infections.

Inhaled EC nicotine has not only been associated with lung inflammation but also has been shown to cause respiratory tract infections. Human rhinovirus (HRV) is the most common pathogen of acute infections in the upper respiratory tract and can induce acute exacerbations of lower airway diseases such as asthma and COPD.[11] Pro-inflammatory cytokine interleukin (IL)-6 is commonly associated with tobacco cigarette smoke exposure and leads to acute lung inflammation. Increased IL-6 levels in sputum have been found in smokers with COPD during virus-induced exacerbations and plays an important role in the progression of COPD severity.[11] Wu et al[11] conducted a study to evaluate whether EC liquid, like traditional cigarettes, increases inflammation and viral infection in primary human airway epithelial cells. Their data suggest that even nicotine-free e-liquid promotes the pro-inflammatory response and HRV infection.[11] Moreover, e-liquid with and without nicotine inhibits the lungs' innate immunity (eg, short palate, lung, nasal epithelial clone 1 [SPLUNC1]) that is involved in lung defense against HRV infection.[11] Electronic nicotine delivery devices cause an increase in the virulence of the colonizing bacteria and viral infection by altering the innate immunity/host response.

The use of flavorings in food products gained public attention in the early 2000s when a microwave popcorn processing plant reported several cases of bronchiolitis obliterans, also known as popcorn lung, among their employees.[12] The pathophysiologic scarring of the alveoli

Chemical	Description	Physiologic impact
Nicotine	Common nicotine Concentrations are 0-24 mg	Sympathomimetic, cardiac, vascular, endocrine, and immunologic toxicity
		Drug-to-drug interactions
Propylene glycol	Artificial flavoring	Carcinogenic
Glycerol	Artificial flavoring	Cardiotoxic, carcinogenic
Diacetyl	Artificial flavoring	Pulmonary toxicity
Acrolein, formaldehyde, and acetaldehyde	Toxic compound generated in aerosol	Pulmonary and vascular toxicity, carcinogenic
Heavy metals	Contained in e-liquid and aerosol	Pulmonary, vascular, and nephrotoxicity
Toluene	Volatile compound generated in aerosol	CNS depressant

Table 3. Constituents of Liquids and Aerosols in E-Cigarettes
Abbreviation: CNS, central nervous system.

in the lungs results in the thickening and narrowing of the small airways.[11] The symptoms of bronchiolitis obliterans include acute coughing, wheezing, shortness of breath, and dry throat similar to the symptoms of COPD.[12] Diacetyl, the same chemical as the butter-flavoring agent in popcorn, is contained in e-liquids and has been associated with the development of pulmonary disorders. In a study conducted by Allen et al,[13] diacetyl was detected in 39 of the 51 flavored e-cigarettes. Because of the associations between diacetyl and bronchiolitis obliterans as well as other severe respiratory diseases among workers inhaling heated vapors containing diacetyl, researchers are warning users against exposure to diacetyl in e-cigarettes. Because of the pathophysiologic changes that occur in EC use, it would make sense that anesthetists should treat long-term vapers with the same anesthetic management as for COPD and reactive airway.

As reported by Goniewicz et al,[14] heating e-liquids with sufficient temperatures produces detectible levels of formaldehyde, acrolein, and acetaldehyde carbonyls. Along with being carcinogenic, these compounds cause irritation to the nasal cavity and damage to the lining of the lungs, attributing to further airway reactivity.[14] Furthermore, chemical composition analysis of e-cigarettes in multiple studies have found that heavy metals are emitted in its aerosol. In 2018, Zhang et al[15] found heavy metals such as tin, nickel, lead, and chromium in the smoke of e-cigarettes. Inhaled heavy metal can be deposited in the alveoli, causing lung damage leading to cough, dyspnea, chest pain, pulmonary edema, and acute respiratory failure.[15] More specifically, iron can produce respiratory irritation, metal fume fever, siderosis, and fibrosis. Magnesium can induce lung irritation, coughing, bronchitis/pneumonitis, reduced lung function, and pneumonia. Copper can produce respiratory irritation, coughing, sneezing, chest pain, and runny nose. Zinc can cause metal fume fever, reduced lung function, chest pain, coughing, dyspnea, and shortness of breath.[16] Evidently, although some metals are essential nutrients when ingested, others can have serious negative effects when inhaled.

Another important consideration that anesthetists must account for are the effects of dual use of conventional cigarettes and EC. If patients are users of both products, additional caution must be taken. Results of a study conducted by Vardavas et al[17] revealed that there was an increase in impedance, peripheral airway flow resistance, and oxidative stress among healthy smokers who also vaped for 5 minutes. As with traditional cigarettes, e-cigarette vapors also have a direct correlation with causing inflammation and apoptosis or necrosis of the respiratory system. Therefore, patients who vape have a higher risk of intraoperative and postoperative pulmonary complications.

• ***Cardiovascular Effects.*** There is sufficient evidence to indicate that e-cigarettes have a significant effect on cardiovascular health. Extensive epidemiologic research suggests that one-third of deaths from cigarette smoke exposure are secondary to cardiovascular disease (CVD).[18] E-cigarettes, although marketed with claims of health benefits compared with smoking cigarettes, have also been shown to have a devastating impact on the cardiovascular system. Nicotine, carbonyls, and other particulates contained in EC aerosol are of main concern regarding CVD.[18] The impact of nicotine on the cardiovascular system has been well documented. Nicotine is a ganglionic and central nervous system (CNS) stimulant that enhances the release of various catecholamines, leading to hemodynamic instability under general anesthesia.[18] Many of the cardiovascular concerns are related to the ability of nicotine to release catecholamines, leading to massive swings in blood pressure, endothelial dysfunction, increase in lipids, and insulin resistance.[18] Acute side effects of nicotine include increases in heart rate, blood pressure, myocardial contraction, myocardial oxygen consumption, myocardial excitement, and peripheral vascular resistance.[19] Nicotine poisoning often causes

System	Change
Pulmonary	• Increased airway hyperreactivity • Increased airway resistance • Increased mucus production • Parenchymal/alveolar inflammation • Increased closing capacity • Interference with lung development • Impaired defense against bacterial and viral pathogens • Nasal airway irritation • Bronchiolitis obliterans
Cardiac	• Hemodynamic instability under GA • Hypertension • Tachycardia • Increased myocardial oxygen consumption • Impaired coronary blood flow • Hyperlipidemia • Atherosclerosis • Impaired cardiac development in pediatric patients • Insulin resistance
Central nervous system	• Impaired brain development in pediatric patients • CNS depression
Immunology	• Antiproliferation of cells • Impaired fibroblast activity • Impaired tissue oxygenation • Decreased collagen
Response to anesthetic agents	• Increased opioid requirement • Decreased sensitivity to NMBDs • Decreased MAC secondary to CNS depression

Table 4. Pathophysiologic Changes With Electronic Cigarette Use
Abbreviations: CNS, central nervous system; GA, general anesthesia; MAC, monitored anesthesia care; NMBD, neuromuscular blocking drug.

nausea, vomiting, dizziness, tremors, diaphoresis, sweating, tachycardia, and seizures and sometimes death.[19] Net effects of nicotine on cardiovascular function include impaired coronary blood flow and an adverse myocardial oxygen supply-demand ratio.[19] Anesthesia considerations for acute nicotine intoxications should be taken into account because anesthetists may be called to emergency departments for rescue intubation of these patients.

StHelen et al,[20] at the University of California, conducted a study to assess nicotine delivery, retention, and pharmacokinetics from various EC. According to the data collected, EC have the ability to deliver an average of 1.3 mg (range = 0.4-2.6 mg) of nicotine from 15 puffs, similar to or higher than average levels of 0.5 to 1.5 mg nicotine per tobacco cigarette.[20] Regarding systemic retention of nicotine, EC yielded an average of 94%, resulting in uptake of approximately 1.2 mg (0.4-2.4 mg) of nicotine from 15 puffs. Systemic retention of nicotine from tobacco cigarettes averages approximately 80% to 90% of the inhaled dose.[20]

Researchers in Sweden found that inhaling e-cigarettes only 10 times can cause signs of damage to the blood vessels.[15] Their study also indicated that the total lipid composition, including the content of saturated fatty acids, increased significantly in rats exposed to e-cigarette smoke and the content of unsaturated fatty acids decreased significantly.[15] Since the nicotine in EC appears to have significant net effects on the vascular system, anesthetists should assess vapers who are undergoing general anesthesia for cardiovascular changes. When the e-liquid is heated, thermal degradation of propylene glycol can generate propylene oxide, which is classified by the International Agency for Research on Cancer as a class 2B carcinogen.[18] Heating glycerol can result in formation of acrolein in the e-liquid. Long-term inhalation of acrolein inhibits circulation of endothelial progenitor cells and promotes atherosclerosis, which accelerates the rate of hardening of the aorta by 1.6 times.[15]

It is well established that smoking has an impact on the embryonic period, most importantly fetal cardiac development and function, leading to a wide range of pregnancy-related problems. In their study of human embryonic stem cells, Palpant et al[21] sought to determine

the impact of EC on cardiac maturity in vitro and in vivo. They observed that as the cells progress to cardiac progenitor cells, there was a decrease in expression of cardiac transcription factors in both e-cigarette aerosol and tobacco cigarette smoke extract.[21] Assessment of e-cigarette smoke showed evidence of inefficient maturation based on an increased incidence of heart defects in developing zebrafish. There was also a reduction in expression of late markers of maturation during the cardiac differentiation period.[21] In conclusion, this study revealed that exposure to e-cigarette aerosol extracts results in detrimental fetal cardiac development, even though they lack most of the chemicals contained in tobacco cigarette smoke extracts.[21] There is sufficient evidence to caution children, adolescents, pregnant women, and women of reproductive age about the use of e-cigarettes because of the potential long-term consequences on cardiac and brain development. However, given the lengthy lag time for onset of many diseases, conclusive evidence about the association of e-cigarette use with such diseases will not be available for years or even decades.

• ***Drug-to-Drug Interactions.*** Anesthetists must be aware of the interactions between EC and anesthetic drugs, including volatile agents, opioids, and neuromuscular blocking drugs.[22] E-cigarettes have been shown to produce volatile organic compounds (VOC), including toluene in almost all samples of smoke detected.[15] Acute inhalation exposure to VOC produces sedation, immobility, anesthesia, and unconsciousness in higher concentrations, and exposure to lower concentrations impairs neurologic function and behavioral performance.[23] More specifically, evidence shows that toluene shares many effects of CNS-depressant compounds such as barbiturates, ketamine, and isoflurane.[24] Along with having anesthetic effects on the CNS, VOC such as toluene are irritating to the skin and mucous membrane and are carcinogenic.[13] Vapers presenting to the operating room for emergent cases may be under the CNS-depressant effects of VOC contained in EC. If patients appear to be under these effects, special care should be taken to adjust to these lessened anesthetic requirements.

Clinical evidence suggests that use of nicotine (which is contained in EC and traditional cigarettes) places patients at an increased risk of chronic pain disorders.[24] Furthermore, nicotine users who have chronic pain have a higher intensity of pain and an increased number of painful sites compared with their counterparts.[25] Nicotine has also been associated with having an increased opioid requirement postoperatively. Although this mechanism is poorly understood, common rationales include alteration in pain thresholds or receptor-mediated tolerance that develops with chronic nicotine use.[22] Evidence also supports that cross-tolerance may develop between nicotine and opioids.[25] The combination of these 2 pharmacodynamic changes places nicotine users at a higher risk of increased opioid requirement. In a prospective cohort study of patients undergoing general anesthesia, researchers found that nicotine users (male participants more than females) required more opioids for up to 72 hours after surgery compared with nonusers of nicotine.[26] The same study suggested that abstinence from nicotine even for 1 day in nicotine-dependent patients appears to result in hyperalgesia or lower pain threshold after surgical procedures.[26] Given the relatively short time that EC have been used, research directly relating to opioid requirements is currently limited in this population. However, considering that EC contain a substantial amount of nicotine (up to 24 mg), surgical patients who vape may also require a higher dose of opioids postoperatively.

Multiple studies have also shown that smoking decreases the potency of aminosteroid muscle relaxants. Long-term smoking is an inducer of the P450 liver enzyme CYP1A2, the same enzyme that metabolizes rocuronium and vecuronium.[27] This explains the higher dose requirement when using these muscle relaxants for long-term nicotine smokers. Furthermore, the continuous agonistic stimuli of nicotinic-cholinergic receptors can lead to a receptor downregulation and a decrease in the number of the overall receptors.[27] As a result, a higher dose of aminosteroid muscle relaxants may be required to reach a therapeutic level during induction. Anesthetists should use peripheral nerve stimulators/accelerometers to guide careful dosing of neuromuscular blocking drugs.[18]

• ***Immunologic Effects: Wound Healing/Infection.*** Some smokers undergoing elective surgery express interest in using EC as a means to abstain from smoking in the perioperative period. Anesthetists must be able to provide facts and statistics related to EC compared with traditional cigarettes when it comes to surgical patients. It is well established that nicotine use in the perioperative period negatively affects surgical outcomes. Nicotine is associated with an increased risk of surgical site infection and necrosis, resulting in delayed wound healing.[28] Because some brands of EC can contain more nicotine than traditional cigarettes, they may have higher detrimental effects on tissue perfusion. in their review of the literature, Fracol et al[28] reported that, in 50 case reports, the use of EC was associated with flap failure and necrosis due to poor tissue oxygenation. Despite limited objective data, evidence suggests that EC may induce some of the same physiologic changes as traditional cigarettes (with or without nicotine present) and may have a significant deleterious effect on wound healing.[28] For example, Fracol et al[28] reported a case of a 51-year-old woman with a 25-pack year smoking history and newly diagnosed right-sided breast cancer who underwent bilateral mastectomy and immediate breast reconstruction using a tissue expander. The patient reported herself as a nonsmoker despite substantial EC use, which resulted

Management stage	Strategy
Education	Recommend cessation of e-cigarette use.
Preparation	• Consider PFTs, chest radiographs, and blood gas analysis to get baseline Pao_2 and $Paco_2$ in long-standing EC users • Obtain cardiac function testing. • Determine amount of EC nicotine use.
Premedication	• Use a antisialogogue agent such as glycopyrrolate to dry secretions. • Use an anxiolytic agent such as midazolam to negate the psychological effects.
Induction and intubation	• Preoxygenate for 3-5 min. • Use intravenous lidocaine to prevent laryngospasm during intubation. • If performing inhalation induction with volatile agents, sevoflurane is preferred. • Avoid airway manipulation during light anesthesia, which may result in coughing, breath holding, laryngospasm, or bronchospasm. • Before intubation, use LTA to anesthetize the larynx and suppress laryngeal hyperreactivity.
Maintenance	• Avoid light anesthesia, which may result in bronchospasm. • Have bronchodilators available for symptomatic smokers. • Avoid desflurane, which is a respiratory irritant and results in higher blood pressure and heart rate. • A higher dose of benzodiazepine, opioid, and muscle relaxants will be required. • Increase minute volume.
Monitoring	• When using current pulse oximeters, remember that a gross overestimation of oxygenated hemoglobin saturation (Sao_2) occurs. • Monitor for signs and symptoms of acute nicotine intoxication. • Pay special attention to changes in blood pressure, heart rate. and rhythm, especially in patients with history of coronary heart disease. • Use a peripheral nerve stimulator to monitor the neuromuscular block since there are various reports on the increased requirement of muscle relaxants. • In long procedures, perform intermittent blood gas analysis to check the $Paco_2$ since $Paco_2$ - $ETCO_2$ gradient is higher than in nonsmoking patients.
Recovery	Do not extubate during light anesthesia because it may result in cough, breath holding, laryngospasm, or bronchospasm.

Table 5. Anesthetic Management of Electronic Cigarette (EC) Users
Abbreviations: $ETCO_2$, end-tidal carbon dioxide; LTA, laryngotracheal topical anesthesia; PFT, pulmonary function test.

in mastectomy skin flap necrosis and breast reconstruction failure.[28] Nicotine is shown to have antiproliferative properties and affects fibroblasts in vitro, which may interfere in tissue myofibroblast differentiation in EC users. This affects the ability to heal wounds by decreasing wound contraction.[29] There is a direct correlation between nicotine intake and decreased collagen synthesis/production. Its use results in a predisposition to prolonged periods of wound healing and higher rates of wound infections.[29] Anesthetists should educate surgical patients regarding the net effects of nicotine found in EC on anesthesia and the process of wound healing.

Discussion

E-cigarettes are gaining popularity as nicotine delivery devices, yet many anesthetists lack the confidence and knowledge to discuss these devices with their patients and families. When patients are asked if they smoke, the answer that anesthetists typically receive is "no" because vapers do not consider the use of EC as smoking. A more appropriate question to ask surgical patients is whether they use any nicotine-based products including EC. Even some EC users are not fully informed regarding its full health effects. Just as it is the anesthetist's duty to provide patients with smoking-cessation education, it is also important that anesthetists include the use of EC in their patient education.

The cornerstones of an effective preoperative evaluation are the medical history and physical assessment. Although it is routine for anesthetists to question patients regarding cigarette smoking, inquiring about the use of e-cigarette smoking has proved to be just as important. Anesthesia providers need to be aware of the deleterious health effects of EC and the considerations for patients undergoing general anesthesia. Table 5 summarizes the anesthesia management for EC users. The pulmonary changes that occur in a patient who uses these devices increase the risk of respiration complications such as laryngospasm or bronchospasm. As with traditional cigarette smokers vapers should be considered to have an increased risk

of reactive airways. Anesthetists may find it beneficial to obtain baseline pulmonary function tests, use bronchodilators preoperatively and intraoperatively when indicated, and deepen the plane of anesthesia before airway manipulation. Because of the effects of nicotine on the cardiovascular system, great care should be taken to prevent and monitor for hemodynamic disturbances that may occur in a patient under anesthesia. The negative ionotropic effects of nicotine lead to chronic tissue hypoxia. Patients should be educated regarding the increased risk of delayed wound healing and infection associated with e-cigarettes. Furthermore, by understanding the pharmacokinetic and pharmacodynamic effects of nicotine contained in EC, anesthetists can be ready to make appropriate judgments regarding opioids, volatile agents, and neuromuscular blocking drugs in patients who use EC.

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