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The effects of vaporization on the respiratory, cardiovascular, skin, oral and dental systems

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Abstract

Introduction:

Vaping, defined as the inhalation of an aerosol generated by electronic nicotine delivery systems (ENDS), has become a rapidly growing public health phenomenon, particularly among adolescents and young adults. Despite the absence of a combustion process, e-cigarettes deliver nicotine along with numerous chemical compounds with potential toxic properties, raising concerns regarding their multisystem health effects.

Materials and Methods:

A narrative–systematic review of the literature published between 2013 and 2025 was conducted. Publications indexed in PubMed, JAMA Network, ScienceDirect, Wiley Online Library, as well as reports from international institutions, were analyzed.

Results:

E-cigarette use has been shown to be associated with multisystem health effects. Within the respiratory system, symptoms such as cough, dyspnea, wheezing, exacerbations of asthma and chronic obstructive pulmonary disease (COPD), as well as cases of acute lung injury (EVALI), have been reported. In the cardiovascular system, endothelial dysfunction, increased arterial blood pressure, and oxidative stress have been observed. Cutaneous manifestations include impaired wound healing and inflammatory processes. In the oral cavity, an increased risk of periodontal disease, dental caries, and microbiome dysbiosis has been identified.

Discussion:

Available evidence suggests that e-cigarettes exhibit biological activity and may induce multisystem health consequences. Although the levels of certain toxicants may be lower than those found in conventional tobacco smoke, this does not imply safety. A key limitation remains the lack of long-term population-based studies.

Conclusions:

Vaping is associated with significant health risks affecting multiple organ systems. Current evidence does not support its safety, and the use of e-cigarettes should be considered potentially harmful. Further research and preventive measures are warranted, particularly among adolescent populations.

Keywords:

Vaping; Electronic Cigarettes; Respiratory Diseases; Cardiovascular Diseases; Skin Disorders; Oral and Dental Diseases; Nicotine Dependence; Inflammation; Oxidative Stress; Public Health

Introduction

Vaping is a behavior that involves the inhalation of an aerosol generated by electronic devices such as e-cigarettes, vape pens, and mods, which heat a liquid (e-liquid) to produce an inhalable aerosol. This aerosol may contain nicotine, flavoring agents, solvents (e.g., propylene glycol and glycerin), and products of thermal degradation; however, it does not result from tobacco combustion, which distinguishes vaping from conventional cigarette smoking [1].

Epidemiology

Available clinical data concerning e-cigarette or vaping product use–associated lung injury (EVALI) indicate that this condition occurs predominantly in young individuals (with a median age of approximately 24 years), with a clear predominance of males, distinguishing it from classical tobacco-related diseases [2]. Exposure patterns are heterogeneous—approximately 80% of EVALI cases are associated with the use of products containing tetrahydrocannabinol (THC), while 50–60% also involve the use of nicotine-containing products [3]. The highest prevalence of e-cigarette use is observed in highly developed regions such as North America and Western Europe; however, the increase in use has a global character [4].

Rising prevalence of vaping among adolescents

Over the past decade, a dynamic increase in e-cigarette use has been observed, particularly among adolescents and young adults. It is estimated that the number of vaping users has exceeded 80 million individuals, with the upward trend being especially pronounced in adolescent populations [4].In the United States, e-cigarettes have become the most commonly used nicotine-containing product among youth, and a substantial proportion of users are individuals who had not previously smoked conventional cigarettes [5].This phenomenon raises particular concern in the context of the so-called gateway effect, which refers to an increased likelihood of initiating conventional tobacco smoking among previously non-smoking individuals [6]. In the United States, e-cigarettes remain the most commonly used nicotine product among students, with the prevalence of use among high school students reaching approximately 10% of the population (around 2.5 million individuals in 2019) [7].

Chemical Composition of Vape Products

Nicotine concentration and variability

Nicotine content in e-cigarettes demonstrates significant variability depending on device type, voltage, e-liquid composition, and user inhalation patterns [8]. Pharmacokinetic studies indicate that nicotine delivery via e-cigarettes may be comparable to that of conventional cigarettes; however, it is characterized by substantial interindividual variability. The lack of product standardization results in difficulty in predicting the actual nicotine dose, which may differ even when identical concentrations are declared in the e-liquid [9].

Flavorings and additives

Numerous flavoring compounds used in e-liquids have been shown to induce damage to respiratory epithelial cells via cytotoxic mechanisms and to enhance inflammatory responses, including increased production of pro-inflammatory mediators and oxidative stress [10]. E-liquids contain a wide range of flavoring substances, such as diacetyl, acetoin, and benzaldehyde, which are generally recognized as safe for oral consumption; however, their safety upon inhalation remains unclear [11]. Studies have demonstrated the presence of benzaldehyde in the majority of analyzed flavored e-cigarettes, and its presence may lead to irritation of the respiratory tract [8].

Toxic substances such as formaldehyde and heavy metals

E-cigarette aerosol constitutes a complex mixture of chemical compounds originating both from the heating of e-liquid components (propylene glycol and glycerin) and from the structural elements of the device. During the thermal degradation of these substances, reactive carbonyl compounds are formed, including formaldehyde, acetaldehyde, and acrolein, all of which exhibit documented toxic effects on the respiratory system [12].

The concentration of these compounds is strongly dependent on technical parameters of the device, such as voltage and operating temperature, with higher values leading to intensified thermal degradation processes and increased toxin production [13]. Additionally, the presence of heavy metals such as lead, nickel, and chromium has been detected in e-cigarette aerosol. These metals most likely originate from the metallic heating elements of the devices, indicating an additional source of exposure [14].

Comparison with conventional cigarettes

E-cigarette aerosol differs significantly from tobacco smoke in terms of its formation mechanism, as it is produced through liquid heating rather than combustion, resulting in the formation of fewer pyrolysis products [15]. Consequently, the number and concentrations of toxic compounds in e-cigarette aerosol are generally lower compared to conventional cigarette smoke, which contains thousands of chemical substances, including numerous carcinogens and combustion products [16]. Comparative studies have demonstrated that the concentrations of selected toxic and carcinogenic compounds in e-cigarette aerosol are several to hundreds of times lower than those in tobacco smoke; however, they are not absent, and their presence remains associated with potential health risks [17]. It should be emphasized that a lower concentration of toxic substances is not equivalent to safety, as e-

cigarette aerosol still contains reactive carbonyl compounds, heavy metals, and fine particulate matter capable of inducing oxidative stress and inflammatory responses within the respiratory system [15]. The technological diversity of devices and the lack of product standardization complicate the accurate assessment of risk, as well as comparisons of exposure levels between e-cigarette users and conventional cigarette smokers [9].

Materials and methods

A narrative–systematic review of the literature published between 2013 and 2025 was conducted. Publications indexed in PubMed, JAMA Network, ScienceDirect, Wiley Online Library, as well as reports from international institutions, were analyzed. Clinical studies, systematic reviews, meta-analyses, and experimental studies addressing the effects of e-cigarettes on the respiratory, cardiovascular, integumentary (skin), and oral systems were included.

Results

Impact on the respiratory system

E-cigarette use constitutes a significant public health concern and has a documented adverse impact on respiratory system function. Available scientific evidence indicates that exposure to aerosols generated by electronic nicotine delivery systems (ENDS) may be associated with both acute respiratory responses and the development of chronic functional impairments and structural alterations within the lungs. This phenomenon raises particular concern in the context of the increasing popularity of e-cigarettes, especially among young adults and physically active individuals. According to reports from the American Heart Association, numerous epidemiological studies and clinical observations have demonstrated an increased risk of lower respiratory tract symptoms among ENDS users. The most frequently reported manifestations include chronic cough, excessive bronchial mucus production, bronchitis, and dyspnea at rest and during exertion. These symptoms are consistently reported across large epidemiological studies, cohort analyses, and survey-based research in both adolescent and adult populations, indicating their prevalence and reproducibility irrespective of age.

A significantly higher frequency of exacerbations of bronchial asthma and chronic obstructive pulmonary disease (COPD) has also been demonstrated, particularly among individuals with pre-existing respiratory conditions [18][19]. Particular attention has been paid to the chemical composition of e-cigarette liquids. The American Heart Association indicates that certain flavoring substances, including diacetyl, exhibit toxic effects on the respiratory tract and may be associated with the development of bronchiolitis obliterans, a condition leading to irreversible narrowing of the bronchioles, commonly referred to as "popcorn lung" [18]. At the molecular level, e-cigarette aerosol has been shown to enhance inflammatory processes within the respiratory tract through increased mucin production, neutrophil activation, and impairment of immune cell function. These mechanisms contribute to weakened local immune responses and increased susceptibility to respiratory infections [18][19]. Experimental studies have also demonstrated alterations in gene expression and the proteomic profile of bronchial epithelial cells, indicating dysregulation of immune responses, including immunosuppression and potentially increased susceptibility to bacterial and viral infections [19]. Additionally, wheezing and episodes of chest tightness are frequently reported, particularly among adolescents and young adults [20][21][22]. The risk and severity of respiratory symptoms increase with the frequency of e-cigarette use, the use of nicotine salts, and exposure to specific types of flavoring substances [21]. Additional accompanying symptoms include throat irritation, oral dryness, nasal and paranasal sinus complaints, as well as the occurrence of fatigue even during minimal physical exertion [23]. In acute cases, particularly in the course of EVALI, more severe clinical manifestations may occur, including hypoxemia and tachypnea, requiring urgent medical intervention [22]. Acute exposure to e-cigarette aerosol components may lead to irritation of the respiratory epithelium, increased airway resistance, and disturbances in respiratory mechanics. These changes are reflected in spirometric parameters, including a reduction in forced expiratory volume in one second (FEV1) and the ratio of FEV1 to forced vital capacity (FVC), suggesting transient airflow limitation [18][19]. An increasing number of clinical reports also indicate direct injury to lung parenchyma associated with e-cigarette use. The literature describes cases of eosinophilic pneumonia, organizing pneumonia, diffuse alveolar hemorrhage, as well as EVALI. This syndrome has resulted in thousands of hospitalizations and numerous deaths in the United States, highlighting the potentially severe course of respiratory complications associated with vaping [18][24][25][26].

2. Impact on the skin

Vaping exerts a documented adverse effect on the skin, primarily manifesting as a variety of dermatological conditions, including contact dermatitis, thermal injuries, and pathological changes of the oral mucosa. These conditions are associated with direct exposure of the skin and mucous membranes to e-liquids, device components, and aerosolized chemical substances that may exert irritant or allergenic effects. Consequently, this leads to the development of localized inflammation, skin irritation, and structural damage [27][28]. Experimental data indicate that vaping may significantly impair the process of cutaneous wound healing. Studies conducted on animal models have demonstrated that exposure to e-cigarette aerosol is associated with reduced expression of vascular endothelial growth factor (VEGF) and decreased microvascular density in skin tissue during the healing process. These findings indicate impaired angiogenesis and delayed tissue regeneration. The observed changes are comparable to those occurring following exposure to tobacco smoke, suggesting that vaping may substantially limit the capacity for proper wound healing [29]. Nicotine present in e-liquids may also be absorbed through the skin, particularly in cases of accidental dermal contact, potentially leading to mild symptoms of systemic toxicity. However, it has been demonstrated that prompt and thorough cleansing of the skin following exposure significantly reduces the degree of transdermal nicotine absorption, thereby decreasing the risk of adverse effects [30]. At the cellular level, vaping induces oxidative stress, DNA damage, and increased production of pro-inflammatory cytokines in epithelial tissues. These mechanisms may contribute to the persistence of chronic inflammation and potentially increase the risk of neoplastic processes. However, it should be emphasized that the long-term consequences of these biological changes have not yet been clearly established and remain the subject of ongoing research [31]. Dermatological adverse effects associated with additives commonly present in e-cigarettes include contact dermatitis, allergic reactions, and thermal injuries. Flavoring substances such as cinnamaldehyde, vanillin, menthol, ethyl maltol, and benzaldehyde exhibit cytotoxic and pro-inflammatory properties, leading to increased apoptosis, reduced cell viability, and enhanced expression of inflammatory cytokines in epithelial and endothelial cells. Clinically, these changes may manifest as erythema, pruritus, eczematous lesions of the skin, as well as irritation and ulceration of the oral mucosa [32][33]. Propylene glycol and vegetable glycerin, which constitute the primary humectants used in e-liquids, are associated with the occurrence of irritant contact dermatitis. Upon heating, they may undergo transformations leading to the formation of reactive aldehydes, such as formaldehyde and acrolein, which are potent irritants to the skin and mucous membranes and substances with documented carcinogenic potential [33–35]. Additionally, the presence of sweeteners and flavoring agents promotes further formation of reactive aldehydes,

which may intensify inflammatory processes in the skin and lead to disruption of the epidermal barrier function [33]. Thermal injuries, including burns and scalds, may occur both as a result of device malfunction and due to direct contact of the skin with heated liquids [27]. Moreover, exposure to selected additives, such as diacetyl or acetoin, may negatively affect wound healing processes and promote the persistence of chronic inflammation, thereby potentially increasing the risk of infection and delaying tissue regeneration [33].

3. Impact on the cardiovascular system

Exposure to aerosols generated by electronic nicotine delivery systems (ENDS) leads to an increase in heart rate and arterial blood pressure, impairment of endothelial function, and increased arterial stiffness. These effects are largely attributable to nicotine and other constituents of the aerosol produced during vaping [1][36][37]. According to the American Heart Association, these hemodynamic changes occur concomitantly with increased sympathetic nervous system activity and reduced bioavailability of nitric oxide, contributing to vascular dysfunction and promoting the development of cardiovascular diseases in the long term [1][38]. Long-term exposure to e-cigarette aerosol is associated with persistent endothelial dysfunction, enhanced oxidative stress, chronic systemic inflammation, and disturbances in autonomic balance. All of these mechanisms constitute established risk factors for myocardial infarction, arterial hypertension, atherosclerosis, arrhythmias, and heart failure [37][39][40]. Studies conducted in animal models, as well as limited clinical data, suggest that prolonged use of ENDS may contribute to increased arterial stiffness, vascular wall remodeling, and myocardial fibrosis. However, it should be emphasized that conclusive epidemiological evidence confirming an increased incidence of clinical cardiovascular events remains limited, which is related to the relatively short period of widespread use of these products [1][41]. The American Heart Association also notes that switching from conventional cigarettes to ENDS may reduce certain markers of vascular injury; however, the independent use of e-cigarettes remains associated with significant adverse cardiovascular effects, particularly among adolescents and individuals with pre-existing cardiovascular conditions [1][38]. The presence of nicotine and selected flavoring substances may further enhance sympathetic responses and inflammatory processes, thereby increasing the risk of adverse outcomes [37].

4. Impact on Oral and Dental Health

The use of e-cigarettes is associated with a range of adverse effects on oral health, including an increased risk of periodontal disease and dental caries, as well as gingivitis, xerostomia, mucosal alterations, and disturbances in the composition of the oral microbiome [42–45].

4.1 Effects on the periodontium and gingiva

The use of e-cigarettes significantly increases the risk of periodontal disease. A study conducted in South Korea demonstrated that e-cigarette users had a 2.34-fold higher risk of periodontal disease compared with non-users, which is comparable to the 2.17-fold increased risk observed in conventional cigarette smokers [46]. Vaping leads to alterations in the oral microbiome, characterized by a reduction in commensal bacteria and an increase in the proportion of pathogens associated with inflammation and periodontal disease [47–48]. These changes are dependent on the intensity of exposure and are more pronounced in individuals who use e-cigarettes frequently, in whom reduced microbial diversity has also been observed [47]. Moreover, e-cigarette users exhibit a distinct oral microbiome profile which, compared with non-users, may demonstrate greater pathogenic potential, manifested by an increased proportion of pathogenic microorganisms and enhanced virulence traits, similar to those observed in patients with advanced periodontitis [43][48]. Epidemiological studies consistently indicate an increased prevalence of gingivitis and periodontal diseases among e-cigarette users [43–44][46].

4.2 Dental caries

E-cigarette use increases susceptibility to dental caries through multiple pathophysiological mechanisms [42]. E-liquids contain components such as propylene glycol, glycerin, nicotine, and flavoring agents, which often include compounds with cariogenic potential, such as sucrose, sucralose, and ethyl maltol [49]. E-cigarette aerosol is characterized by high viscosity, and its components exhibit the ability to adhere to oral surfaces, promoting their retention on tissues and creating an environment conducive to the development of dental caries [49]. Both vaping and conventional cigarette smoking demonstrate a significant association with the occurrence of dental caries, tooth pain, and structural damage to dental tissues [46].

4.3 Oral mucosal changes and clinical symptoms

The most frequently reported oral symptoms among e-cigarette users include xerostomia, irritation, and mucosal alterations [43][45]. It has been demonstrated that individuals using e-cigarettes more

frequently experience conditions such as nicotine stomatitis, hairy tongue, and angular cheilitis compared with former smokers [44]. Although most oral and pharyngeal symptoms are mild and transient in nature, they are consistently reported in clinical and epidemiological studies [45]. Additionally, it has been shown that aerosol carriers based on propylene glycol and glycerin can modify the structure of the oral microbiome within a short period (even within 24 hours of exposure), which may be relevant to the pathogenesis of oral diseases [48].

4.4 Cellular effects and carcinogenic potential

Components of e-cigarette aerosol have demonstrated cytotoxic, genotoxic, and potentially carcinogenic effects in laboratory studies [42][45]. Nicotine-containing aerosol may constitute a risk factor for the development of oral cancers due to the presence of compounds with carcinogenic properties; however, long-term clinical data in this area remain limited [42]. Analyses indicate that e-cigarette use is associated with activation of pathways related to lipid metabolism, inflammatory processes, and xenobiotic detoxification, along with alterations in metabolite profiles linked to pathways involved in the progression of oral cancers [47].

4.5 Peri-implant diseases

The use of e-cigarettes is associated with an increased risk of peri-implant diseases, demonstrating an effect comparable to that observed in conventional cigarette smokers [42].

4.6 Comparison with conventional cigarettes

In vitro studies indicate that the effects of e-cigarettes on cells are less pronounced than those observed with tobacco smoke; however, clinical data suggest a comparable negative impact on periodontal tissues [43][49]. In smokers who use e-cigarettes as a tool for smoking cessation, the potential benefits associated with discontinuation of conventional tobacco use may, in the short term, outweigh the negative impact on oral health. However, this relationship does not apply to individuals who have never smoked and initiate e-cigarette use [43].

Discussion

Available evidence from the literature indicates that e-cigarettes exert a complex, multisystem biological impact on the respiratory, cardiovascular, integumentary, and oral systems. ENDS aerosol contains compounds with toxic potential, including carbonyl compounds, heavy metals, and flavoring agents, which may induce oxidative stress and inflammatory responses. Within the respiratory system,

symptoms such as cough, dyspnea, asthma exacerbations, and cases of acute lung injury (EVALI) have been observed. In the cardiovascular system, endothelial dysfunction and increased arterial blood pressure have been demonstrated. Impairment of skin wound healing, as well as an increased risk of periodontal disease and dental caries, have also been reported. Although exposure to certain toxicants may be lower than in conventional tobacco smoke, this does not imply safety of e-cigarette use. A major limitation remains the lack of long-term population-based studies and the variability in product composition.

Conclusions

E-cigarettes are not biologically inert and may induce significant health effects across multiple organ systems. The most well-documented adverse effects involve the respiratory, cardiovascular, and oral systems. Current evidence does not confirm the safety of ENDS; therefore, their use should be regarded as potentially harmful, particularly among adolescents and young adults. Further long-term studies and preventive strategies aimed at reducing their prevalence are required.

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