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After 20 Years on the Market: The Current Outlook on E-Cigarette Use Among Youth

Katarzyna Drewnowska
National Medical Institute of the Ministry of the Interior and Administration, Warsaw, Poland
https://orcid.org/0009-0007-9388-3533
Corresponding author: kat.dre.99@gmail.com

Jakub Modrzewski
National Medical Institute of the Ministry of the Interior and Administration, Warsaw, Poland
https://orcid.org/0009-0003-0208-2046

Julia Radziszewska
National Medical Institute of the Ministry of the Interior and Administration, Warsaw, Poland
https://orcid.org/0009-0005-5112-0381

Agata Drozd
Medical University of Gdańsk, Poland
https://orcid.org/0009-0004-7083-3718

Agata Kościelniak
Independent Public Healthcare Center in Pruszków, Poland
https://orcid.org/0009-0005-8088-4452

Klaudia Danielewicz
The District Medical Center in Grójec, Poland
https://orcid.org/0009-0006-6767-3906

Agata Rypińska
National Medical Institute of the Ministry of the Interior and Administration, Warsaw, Poland
https://orcid.org/0009-0000-6117-7676

Zofia Kupczyk
Independent Public Healthcare Institution in Mińsk Mazowiecki, Poland
https://orcid.org/0009-0006-7945-8605

Julia Kuźmiuk
Independent Public Healthcare Institution in Mińsk Mazowiecki, Poland
https://orcid.org/0009-0008-7474-4666

Klaudia Piskorowska
5th Military Hospital with Polyclinic in Cracow, Poland
https://orcid.org/0009-0000-9134-0745

Łukasz Kreft
Military Institute of Medicine – National Research Institute, Warsaw, Poland
https://orcid.org/0009-0006-9865-6906

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ABSTRACT

Introduction. Electronic nicotine dispensing systems, commonly known as e-cigarettes, remain the most widely used tobacco product among the youth, with current worldwide use estimated at approximately 5 to 7%. Nevertheless, several aspects of knowledge on their sustained consumption are based on suppositions, such as their role as a "gateway" into cigarette smoking for new generations and the potential subsequent renormalisation of tobacco use. Moreover, recent clinical trials and toxicological assessments have yielded noteworthy findings, revealing their potential to cause tissue damage in the lungs, heart, and oral cavity.

Material and methods. PubMed searches yielded 253 studies on e-cigarette use among youth, of which 78 met inclusion criteria (original data, published between 2000 and July 1, 2025). Keywords covered "electronic cigarette," "e-cigarette," "ENDS," "electronic nicotine delivery system," "electronic nicotine delivery device," and "EVALI."
Results. This narrative review offers a synthesis of the current state of knowledge on e-cigarette consumption patterns and their influencing factors, the public health implications of sustained use, and recent policy developments, along with their presumed effectiveness.
Conclusions. We aim to inform clinicians and youth caregivers about the high prevalence of e-cigarette use among adolescents and present clinically relevant information derived from the latest empirical evidence.

Introduction

Electronic cigarettes continue to be used by millions around the world, particularly among the younger population. A total of 1.63 million (5.9%) American students currently use e-cigarettes, including 410,000 middle schoolers and 1.21 million high schoolers [1]. Since e-cigarettes are combustion-free, there is a widespread assumption that their use is much safer than that of conventional cigarettes [2]. Similar messages are conveyed in e-cigarette advertisements, often featuring celebrities, which are widely present throughout social media to reach their audience most effectively. Along with the ability to bypass smoke-free laws by enabling users to "smoke anywhere" [3], e-cigarettes have become a step toward the normalisation of smoking behaviour. All of this occurs in the context of the widespread and continued availability of conventional cigarettes and other tobacco products, with high levels of dual use [4]. Despite evidence that the toxins present in e-cigarette aerosol can compromise both heart and lung function [5], long-term health risks associated with their use are not yet fully established.

This paper provides a contemporary overview of e-cigarette use patterns among adolescents, critically examines the current evidence regarding their health impacts, and discusses prospective public health implications associated with their sustained use.

Material and methods

Initial searches conducted via PubMed yielded 253 studies. Keywords included "electronic cigarette," "e-cigarette," "ENDS," "electronic nicotine delivery system," "electronic nicotine delivery device," and "EVALI." Articles or abstracts presenting original data on any topic relevant to e-cigarette use among youth, published between 2000 and July 1, 2025, were included. Articles that were not relevant, not in English, or were reviews or commentaries without original data were excluded; however, some were cited for background and context. We also reviewed technical reports prepared by health organisations, news articles, and relevant websites. The final reference list was determined based on relevance to the main topic, resulting in a total of 78 articles forming the basis for this review. Given the scope and heterogeneity of the available literature, a narrative review format was chosen to allow for a more flexible and interpretive synthesis.

E-Cigarette use and device characteristics

Electronic nicotine dispensing systems (ENDS), commonly known as electronic cigarettes or e-cigarettes, were invented in their current form by Chinese pharmacist Hon Lik in the early 2000s [6]. They first appeared on the market over a decade ago, becoming widely available around 2013. In 2024, e-cigarettes were the most commonly used tobacco product among middle and high school students in the United States. A total of 1.63 million (5.9%) students currently use e-cigarettes, with 26.3% of them using an e-cigarette every day [1]. The current use rate was higher among females than among males. Prevalence has mostly remained stable in recent years, following a peak in 2019 when it exceeded 20% [7].

Device evolution

The evolution of ENDS spans four generations. First-generation devices, known as "cigalikes,"

are designed for single use. Second-generation e-cigarettes feature rechargeable batteries and replaceable pre-filled pods, which may contain traditional e-liquid or tetrahydrocannabinol (THC) oil. Third-generation devices, such as tanks or mods, are larger, more customizable, and capable of producing higher aerosol volumes. "Sub-ohm" models, featuring low-resistance coils, provide greater nicotine delivery through increased heat and vapour production. Fourth-generation e-cigarettes use nicotine salts, enabling smoother inhalation of high nicotine concentrations with fewer side effects; compatible pods may also contain cannabidiol.

Consumer preference

Several studies have examined consumer preferences for e-cigarette attributes. Starting with device type, a pooled analysis by Barrington-Trimis et al. [8] involving 2,166 adolescent and young adult e-cigarette users found that fewer than 15% primarily used disposable/cigalike devices in the past month. In contrast, 77% reported using later-generation devices. More recent data from an online survey of 636 Australian users aged 12 and older showed that 82% used nicotine-containing e-liquids, 60% used non-nicotine variants, and disposable e-cigarettes were most common among those under 25 [9].

Findings show that flavour is the primary reason adolescents try e-cigarettes [9]. In a U.S. national survey of 2,253 individuals aged 14–20, 92% of past 30-day e-cigarette users reported using at least one non-tobacco flavour – most commonly sweet (76%) or menthol/fruit-ice (70%) [10]. Latent class analysis identified four flavour preference groups: mint, no preference, fruit/sweet, and flavour aversion. Compared to the no preference group, those favouring fruit/sweet or mint flavours were more likely to have used e-cigarettes ≥50 times. Notably, fruit/sweet preference was negatively associated with combustible tobacco use.

Marketing and promotion of e-cigarettes

E-cigarettes entered the U.S. market around 2006–2007, and since then, the promotion and distribution channels for these products have undergone significant evolution. Marketing expenditures can be traced back to 2008 for approximately 130 e-cigarette brands [11]. The minimal spending through 2010 was followed by an acceleration from $12 million in 2011 to $125 million in 2014. The trajectory for spending was consistent with the pattern for product sales.

It is noteworthy that the product class took hold when e-commerce was rapidly expanding in the United States, and major social media platforms – such as Facebook (founded in 2004), YouTube (2005), and Twitter (2006) – were emerging [12]. In this environment, information about new products like e-cigarettes can spread rapidly across regions, facilitating swift adoption. To assess the magnitude of this effect, Peak et al. [13] conducted a content analysis of 365 e-cigarette–related videos on YouTube, published between June 2007 and June 2011. They estimated that more than 1.2 million youth and approximately 15.5 million individuals worldwide were exposed to these clips. Only 16% of the videos were formal advertisements or news segments, while 79.2% were coded as user-generated content. E-cigarette companies or their affiliates sponsored the majority (85.2%) of the videos.

As of July 2022, the Institute for Global Tobacco Control identified 109 countries or jurisdictions that regulate or ban ENDS, counting 31 distinct e-cigarette regulatory policy approaches [14]. However, the effectiveness of these regulatory measures remains a subject of investigation. The most recent cross-sectional study on this topic analysed data from 165,299 respondents across 48 countries, with a mean participant age of 14, following the 2016/2018 World Health Organisation Framework Convention on Tobacco Control implementation reports. Approximately one in ten respondents reported current e-cigarette use [15]. Only internet tobacco advertising, promotion, and sponsorship (TAPS) bans were found to be effective across all countries. Additionally, in lower-middle-income and low-income countries, bans on displaying tobacco products at the point of sale, bans on product placement, and the strength of additional TAPS measures were associated with a lower prevalence of e-cigarette use among students, as well as being taught about the dangers of tobacco use in school. Surprisingly, no significant differences in e-cigarette

use were observed across TAPS policy types in high-income countries.

Some practitioners argue that the limited effectiveness of e-cigarette regulatory measures may stem from significant delays in their implementation, which allowed marketing materials to spread widely across jurisdictions and capitalise on the most profitable strategies for reaching potential consumers. A primary example is the case of the United States Food and Drug Administration (FDA), which repeatedly postponed the enforcement of its first major regulatory policy – the premarket tobacco product application – until August 2022. It was only after a lawsuit was filed against the FDA by various public health advocacy groups, citing the delays surrounding e-cigarette reviews, that the deadline was ultimately moved forward to May 2020. Despite this adjustment, the U.S. e-cigarette market remained largely unregulated in terms of distribution and marketing for approximately 14 years.

The ensuing backlash accompanying these events was directed primarily at the company JUUL, which was widely criticised for its central role in the youth e-cigarette epidemic. Considerable attention was focused on cartridge-based e-cigarettes with fruity and sweet flavours – products that significantly contributed to JUUL's sales growth and were found to be particularly appealing to youth – ultimately leading to pressure on the company to withdraw them from the market [16]. In light of these concerns, in April 2020, the FDA issued a final enforcement guidance with the intention to implement stricter controls over the marketing of ENDS flavoured products. By September 2021, the FDA had issued approximately 946,000 Marketing Denial Orders, and as of January 2024, not a single flavoured ENDS manufacturer had received authorisation to market their product [17].

Studies aimed to illustrate the impact of flavoured e-cigarette regulations report mixed findings. A cross-sectional study conducted by Ali et al. [18] found that statewide restrictions on non-tobacco-flavoured e-cigarette sales were associated with a 25.01% to 31.26% reduction in total e-cigarette unit sales compared to states without such restrictions. Conversely, other research has identified a marginally significant shift of 0.7 to 1.9 percentage points from e-cigarette use to combustible cigarette smoking, particularly among individuals aged 18 to 20 [19]. Additional studies indicate that users often circumvent flavour bans by obtaining products through in-state stores (45.1%), out-of-state retailers (31.2%), online sources (25.5%), or informal channels [20]. Moreover, some users transitioned from restricted cartridge-based products to flavoured disposable e-cigarettes, the sales of which surged from 29.9% to 49.6% [21].

Neurobiological mechanisms of dependence

The National Institute on Drug Abuse reports that tobacco use is primarily established during adolescence, with nearly 90% of adult smokers starting before the age of 18 [22]. Youth are particularly vulnerable to nicotine addiction, with even infrequent use significantly increasing the risk of dependence. Adolescent smokers are also the most likely to relapse and are more vulnerable to peer pressure, which makes them more susceptible to smoking relapse after cessation [23].

During adolescence, nicotinic acetylcholine receptors remain functionally immature. These receptors are widely distributed across neuroanatomical regions associated with tobacco addiction [24], and their activation regulates monoaminergic neurotransmitter systems, particularly dopamine, which plays a key role in reward processing and drug reinforcement. In rodent studies, the expression and binding of specific nicotinic acetylcholine receptor subtypes are higher in many brain regions during adolescence compared to adulthood [25].

Furthermore, nicotine more robustly enhances neuronal activity in adolescents than in adults, as indicated by increased c-fos mRNA expression in several reward-related brain regions, including the nucleus accumbens shell, basolateral amygdala, and ventral tegmental area [26].

The altered neuronal sensitivity to nicotine during adolescence is paralleled by behavioural responses [27]. Following nicotine exposure, adolescent rodents exhibited increased locomotor activity and reduced anxiety [28]. They also associated nicotine with greater rewarding effects and self-administered higher amounts of nicotine compared to adults [29]. In contrast, adolescent rodents demonstrated lower aversion to

nicotine and experienced less pronounced withdrawal symptoms than their adult counterparts [30]. This shift in the balance between nicotine's positive and negative effects during adolescence may contribute to increased vulnerability to nicotine dependence.

The heightened vulnerability, coupled with the increased likelihood of relapse, constitutes alarming evidence that strongly supports the implementation of stricter age restrictions on the purchase of e-cigarettes. In parallel, the development of comprehensive school-based interventions focused on early education is essential to increase legal awareness, heighten harm perception, and reduce the likelihood of current or future e-cigarette use among youth.

E-Cigarettes as a gateway to nicotine addiction

Over recent years, the proportion of U.S. youth using electronic cigarettes has remained high. This trend has raised concerns that e-cigarettes may contribute to the renormalisation of tobacco use and initiate new generations of youth into cigarette smoking, potentially reversing decades of progress in reducing tobacco-related disease and mortality [31].

A range of research approaches has been employed to evaluate this theory. Barrington-Trimis et al. [32] conducted a prospective cohort study of approximately 300 11th–12th graders (mean age 17.4), comparing never-smoking e-cigarette users (n = 146) to never-smoking, never-e-cigarette users (n = 152). Participants reported their use of e-cigarettes, cigarettes, cigars, pipes, and hookah at baseline and follow-up (~16 months). Cigarette initiation occurred in 40.4% of e-cigarette users versus 10.5% of never users, with e-cigarette users having 6.17 times the odds of initiating cigarette use. This association was stronger among those initially reporting no intention to smoke. E-cigarette users were also more likely to begin any combustible tobacco use.

Berry et al. [33] conducted a prospective cohort study using Waves 1–3 (2013–2016) of the Population Assessment of Tobacco and Health Study, including 6,123 youth aged 12–15. By Wave 3, cigarette use was reported by 20.5% of prior e-cigarette users, compared to 3.8% of those with no prior tobacco use. Prior e-cigarette use was linked to over four times the odds of ever smoking and nearly three times the odds of current smoking. Between 2013 and 2016, it was estimated that 21.8% new cases of ever cigarette use (178,850 youth) and 15.3% of current cigarette use (43,446 youth) could be attributed to prior e-cigarette use. These findings suggest that e-cigarette use may contribute to cigarette smoking initiation at the population level.

Additionally, a meta-analysis of 25 longitudinal studies conducted by Baenziger et al. [34] found evidence that young never-smokers and non-smokers who use e-cigarettes are about three times as likely as non-users to start smoking tobacco and to become regular smokers. All included studies identified elevations in risk.

On the contrary, in their paper exploring the gateway theory in the context of e-cigarettes, Bell and Keane [35] suggest that the theory itself, often treated as a straightforward concept, in the case of e-cigarettes, is rather a retroactively assembled notion. Since the "gateway" in question is from nicotine to nicotine, the same substance is portrayed as both innocuous and harmful. Etter [36] offers a similar perspective and argues that the experiments used to assess the gateway theory cannot account for all the variance in smoking propensity, as most are observational studies that solely adjust for confounders. He warns that policies based on this theory could have adverse consequences on smoking rates, particularly if common liabilities better explain the association between vaping and smoking. If access to less harmful alternatives to combustible cigarettes is restricted, more young people may resort to smoking rather than adopting new alternative technologies.

A significant new concern has recently emerged alongside evidence that the nicotine content of e-cigarettes has increased over time [37]. At present, a substantial proportion of e-cigarettes contain nicotine salts, which allow users to consume high levels of nicotine without experiencing the harshness associated with free-base nicotine [38]. In fact, high-nicotine products dominate U.S. e-cigarette unit sales. As of March 2022, products with a nicotine strength of 5% or more accounted for 81% of total e-cigarette unit sales. Moreover, in recent years, the price of high-nicotine products has decreased

or remained stable, while the cost of low-nicotine products has increased [39]. Even if gateway effects are not currently substantial, this could change in the future if newer e-cigarette models prove significantly more addictive than current ones.

Considering the evidence presented above, the gateway theory cannot be confidently accepted at this time. Clearly determining whether the relationship between e-cigarette use and combustible cigarette smoking is causal or merely correlational remains a critical priority.

Health Outcomes of e-cigarette use

Understanding the harms of prolonged e-cigarette use requires examining e-liquid composition, which typically includes propylene glycol, vegetable glycerin, nicotine, flavourings, and other additives [40]. While propylene glycol and vegetable glycerin are considered safe for ingestion, their long-term inhalation effects remain unclear. Similarly, flavourings deemed "generally recognised as safe" by the FDA apply to ingestion, not inhalation [41]. Margham et al. [42] investigated the chemical composition of e-cigarette aerosols and discovered that they encompass a diverse array of volatile organic chemicals, including aldehydes, ketones, and hydrocarbons. Additionally, in the case of cannabis-containing e-liquids, a commonly used thickening agent is vitamin E acetate, which has been strongly linked to e-cigarette or vaping product use-associated lung injury (EVALI) [40].

Physical health problems associated with the use

The current state of research on the adverse effects of e-cigarette use on physical health indicates that, although e-cigarettes may be considered a safer alternative to combustible cigarettes, their chronic use is not free of health risks. The chemicals and oxidant metals present in aerosols from e-cigarette use have the potential to cause damage to tissues in the lungs, heart, and mouth [5]. There is evidence of nicotine-containing e-cigarettes causing poisoning and immediate inhalation toxicity (including seizures, dizziness, nausea, and vomiting), particularly in children and adolescents [43].

Around the turn of the millennium, concerns emerged regarding the safety of diacetyl, a flavouring agent commonly used in e-liquids to produce a buttery flavour [44]. This compound was associated with the onset of bronchiolitis obliterans, a severe pulmonary condition colloquially known as "popcorn lung", in workers at a microwave popcorn factory. The disease is characterised by inflammation and scarring of the lung tissue, leading to airway obstruction [45]. Propylene glycol, another frequently used e-liquid component that facilitates the mixing of other ingredients, has been shown to damage the epithelial lining of the airways and impair cellular repair mechanisms [46]. This may pose risks for e-cigarette users with chronic obstructive pulmonary disease. In addition, vegetable glycerin has been found to interfere with normal nasal function, potentially leading to the production of thicker mucus and an increased risk of inflammation and compromised airway function [47].

According to research conducted by the Center for Tobacco Research and Education at the University of California, San Francisco, daily use of e-cigarettes can also double the risk of heart attack [48]. This study, which involved nearly 70,000 participants, found that the elevated risk of heart attack among e-cigarette users is comparable to that of combustible cigarette users. Among individuals who use both combustible cigarettes and e-cigarettes daily, the risk increases five times.

The oral cavity is the first site of exposure to nicotine and other chemicals in e-cigarette aerosol. Pushalkar et al. [49] found that e-cigarette users exhibited significantly altered oral microbiome beta-diversity and elevated levels of interleukins IL-6 and IL-1β, indicating an inflammatory immune response. E-cigarette aerosol also induced hypoxia and oxidative stress, increasing epithelial susceptibility to infection.

The adverse effects of e-cigarette use may further compromise oral health through different pathways. Propylene glycol degrades into compounds toxic to enamel and soft tissue, contributes to xerostomia, and promotes caries and gum disease. Vegetable glycerin enhances microbial adhesion and biofilm formation while also reducing enamel hardness [43]. Additionally, nicotine's vasoconstrictive effects impair gingival blood flow and immune responses and increase the risk of periodontal disease and tooth loss [49].

To enable a general comparison, it is worth recalling the adverse health risks connected to other forms of nicotine consumption, including nicotine replacement therapy. Smoking of combustible cigarettes was linked to elevated risks of multiple systemic diseases – including cardiovascular, digestive, musculoskeletal, endocrine, metabolic, and eye disorders – and a range of cancers, such as lung, head and neck, oesophageal or pancreatic cancer. Evidence linking nicotine replacement therapy use to serious adverse health effects is limited, with one study suggesting a possible association with respiratory congenital abnormalities, while no clear links were found for cardiovascular, reproductive, cancer, or stroke-related outcomes [50]. Dual use of both e-cigarettes and combustible cigarettes appears to be associated with greater health risks than the use of either product alone. A recent meta-analysis reported significantly higher odds ratios for various disease outcomes – including chronic obstructive pulmonary disease, cardiovascular events, and asthma – among dual users [51]. Another study found that dual users had significantly higher odds of experiencing incident respiratory symptoms within the past 12 months [52]. To date, this issue remains a subject of ongoing investigation, with the available evidence too limited to permit definitive conclusions.

Mental health problems associated with e-cigarette use

Depression and depressive symptoms seem to emerge more often in adolescent e-cigarette users than non-users [53]. This theory was explored in a study conducted by Dunbar et al. [54], which included 2,039 youths. Participants completed three web-based surveys over the course of three years, beginning at age 16 and continuing until age 20. The subsequently created model assessed the correlation between e-cigarette use and mental health symptoms over time and revealed no associations between the two.

Leventhal et al. [55] investigated psychiatric comorbidity among 3,310 ninth-grade students (mean age 14) in Los Angeles. Participants completed self-reports on e-cigarette/conventional cigarette use, emotional disorders, substance use, and transdiagnostic psychiatric phenotypes. E-cigarette-only users reported lower levels of internalizing symptoms and transdiagnostic traits (e.g., distress intolerance, anxiety sensitivity) compared to conventional cigarette users. However, depression, panic disorder, and anhedonia were higher among e-cigarette users than non-users. An ordered pattern of externalizing outcomes (e.g., mania, substance use) and anhedonia was observed: lowest in non-users, moderate in single-product users, and highest in dual users.

Research findings suggest that use of e-cigarettes could be associated with higher suicidality. This hypothesis was assessed by a study conducted by Lee and Lee [56], in which they examined the results of the 2017 Korean Youth Risk Behavior Web-based Survey of 62,276 students. The statistical analysis of the association between suicidality and patterns of cigarette use revealed that, for lifetime use, e-cigarette-only users were three times more likely to have engaged in suicide planning and five times more likely to have made a suicide attempt than non-users. Additionally, current e-cigarette-only users were six times more likely to have made a suicide attempt than non-users.

Although these studies present promising findings, they are subject to several limitations and should be interpreted with caution. First, the data were self-reported, introducing the possibility of information and/or recall bias. Neither the type nor the nicotine content of e-cigarettes was assessed, limiting the ability to determine whether a higher e-cigarette use profile is genuinely associated with an increased prevalence of depressive and suicidal behaviors. Moreover, it is possible that the causal relationship between e-cigarette use and depressive symptoms operates in the opposite direction from what was assumed in the studies. Previous research has demonstrated that adolescents who use e-cigarettes are more likely to engage in risk-prone behaviors than non-users, and that adolescents with problem behaviors are more prone to depression [56]. To address this issue, future research should include externalizing behaviors as potential confounding variables in the analysis.

EVALI

EVALI is a syndrome, with no specific diagnostic test that defines the condition. According to the CDC criteria, confirmed cases are defined as the onset of pulmonary infiltrates on chest X-ray

or computed tomography that occur within 90 days of e-cigarette use, with no alternative cause found after medical assessment [57].

It was officially identified and named in 2019 because of its outbreak in March 2019, when a cluster of cases emerged in the USA of patients who had developed lung injuries associated with using e-cigarettes. As of February 2020, more than 2,800 patients had been admitted to various hospitals in the US due to an EVALI, with 68 deaths reported so far [58]. It has been reported in a broad age range but was most common in young males between the ages of 18 and 24 years [59].

EVALI was primarily linked to the inclusion of vitamin E acetate in e-liquids, mainly from THC-containing e-cigarettes, largely, but not exclusively, from informal sources [60]. Vitamin E acetate was often used as a thickening agent, likely to dilute THC oil without significantly altering its viscosity. Studies show that it can impair breathing and, when heated, decomposes into harmful compounds such as ketene, alkenes, and benzene, all of which can damage lung tissue [61]. In fact, the CDC found vitamin E acetate present in the bronchoalveolar lavage fluid of most EVALI patients and in product samples associated with the outbreak.

Furthermore, research indicates that vitamin E acetate interferes with the normal function of lung surfactant. It can disrupt the performance of the surfactant system by interfering with the kinetic lipid processes that stabilize the monolayer under compression, contributing to the respiratory distress associated with EVALI [62].

EVALI typically presents as an acute or subacute respiratory illness characterized by nonspecific symptoms, including dyspnea, cough, chest pain, and/or hemoptysis [63]. The majority of patients also exhibit gastrointestinal manifestations (such as nausea, vomiting, and/or diarrhea) and/or constitutional symptoms (including fever, chills, fatigue, and/or weight loss), which tend to develop over a period of days to weeks. On physical examination, patients commonly present with fever (33%), tachycardia (63%), and tachypnea (43%). Additionally, impaired oxygenation is frequently observed, with approximately one in four patients demonstrating a pulse oxygen saturation of ≤89%. Laboratory findings are generally nonspecific and may include leukocytosis and an elevated erythrocyte sedimentation rate.

In certain cases, the clinical presentation of EVALI associated with vitamin E acetate in adolescents appears to differ from that observed in adults. One case series reported that adolescents with EVALI experienced significant weight loss secondary to gastrointestinal symptoms, necessitating hospitalization [64]. Another series described the use of venovenous extracorporeal membrane oxygenation to manage EVALI in adolescents with preexisting asthma [65]. Although the pathophysiology of EVALI in adolescents remains not fully understood, it is reasonable to suspect a distinct clinical presentation in terms of symptomatology, severity, or both.

No randomized clinical trials have evaluated specific therapies for EVALI, and long-term outcome data remain limited. Cessation of e-cigarette use is essential, as continued vaping has been linked to recurrent EVALI and respiratory failure [66]. Supportive care is the primary treatment, typically involving supplemental oxygen (target saturation 88–92%) via nasal cannula, high-flow oxygen, or high-flow nasal cannula. Mechanical ventilation, required in ~26% of cases, follows lung-protective strategies used in acute respiratory distress syndrome [63]; extracorporeal membrane oxygenation is rarely needed.

Infectious causes must be ruled out, with testing for influenza and empiric antiviral/antimicrobial therapy recommended. Patients with severe lung injury and suspected EVALI have shown favourable responses to systemic corticosteroids [67], though their efficacy has not been formally studied. Given the risk of worsening undiagnosed infections, pulmonologist consultation is advised before initiating corticosteroids.

The Future Perspectives

Emerging novel technologies offer promising solutions to combat current challenges in e-cigarette cessation. A variety of digital health interventions help establish a more inclusive and readily accessible healthcare environment [68], offering innovations such as interactive text-messaging programs that remotely deliver cognitive-behavioural coping strategies and peer support. The capabilities of artificial intelligence keep extending across various domains – machine learning enables predictive modelling of

relapse risk and tobacco initiation patterns, while reinforcement learning optimises personalised cessation interventions based on user engagement data [69]. Novel pharmacological options are also being studied – the first U.S. placebo-controlled randomized trial of varenicline for e-cigarette cessation showed promising results, revealing a 15% higher quit rate in the medication group (45%) compared to the control group [70].

Concerning future regulatory policy, beginning at the federal level, agencies responsible for protecting public health should assert their regulatory authority by requiring e-cigarette manufacturers to register their products, disclose ingredient lists, and comply with good manufacturing practices. In addition, manufacturers should be obligated to address the presence of impure or untested additives, resolve issues related to misbranding, and adhere to strict regulations on marketing and sales. It is essential to accelerate the implementation of evidence-based interventions, such as reducing youth exposure to smoking imagery in media, conducting robust counter-marketing campaigns, and ensuring equitable access to tobacco dependence treatment for all who are seeking to quit. Further state policy measures may include increasing the cost of e-cigarettes and restricting their sale exclusively to adult consumers. Additionally, school-based policies, such as banning the use of e-cigarettes on school grounds and/or implementing prevention and cessation programs, represent an important context for shaping youth tobacco use behavior. Equally important is the pursuit of novel solutions and maintaining openness to innovative approaches in responding to emerging public health challenges. However, it is crucial to proceed cautiously, as overly restrictive policies may support the established tobacco industry, encourage the poly-use of tobacco products, and, as a result, perpetuate sales of conventional cigarettes well into future decades rather than hurry their disappearance.

Applied to tobacco, the most effective strategies for harm reduction are those that promote cessation among current users and prevent initiation among non-users. In this context, the role of e-cigarettes remains a complex public health issue due to their dual influence on population health outcomes. On one hand, e-cigarettes can serve as a harm reduction tool for current smokers, for whom switching completely to e-cigarettes may significantly reduce exposure to harmful combustion-related toxins. On the other hand, the concern that e-cigarette use among adolescents introduces nicotine dependence cannot be ruled out.

Carefully framing public health messaging may be one of the keys to navigating this complex issue. One example would be avoiding binary messaging that might discourage combustible cigarette smokers from switching. Another is crafting messages that support cessation without inadvertently attracting youth or downplaying risks for non-users. A complementary strategy should focus on removing features that make e-cigarettes disproportionately appealing to youth, such as by promoting adult-only sales environments or limiting flavor profiles and marketing tactics known to attract adolescents. To ensure the effectiveness of such efforts, continuous monitoring of relevant data is essential, including current trends in youth e-cigarette use and updates on the efficacy of e-cigarettes in smoking cessation. New policies should evolve accordingly and adapt in the shortest possible time to avoid negative public health consequences resulting from legislative delays.

Conclusions

This review aimed to summarise and systematise the current state of knowledge on various aspects of e-cigarette use among adolescents. Extensive research has demonstrated that, in this particular age group, the central nervous system is especially sensitive to the effects of nicotine, making it more likely for nicotine addiction to develop and persist over time. Nevertheless, to date, definitive evidence supporting the "gateway theory" is lacking. Current research findings conclude that e-cigarettes are responsible for the development of EVALI and suggest that they may cause lung injury; many of their chemical components have been linked to adverse health effects. Several aspects of e-cigarette consumption among youth remain poorly understood. Future research should focus on the chemical safety of e-liquids, examine the stability of their ingredients when heated, and identify potential by-products resulting from thermal degradation. It is essential to determine

the long-term health outcomes of e-cigarette use and evaluate their effectiveness as a smoking cessation tool. The "gateway theory" requires confirmation through further high-quality trials. Based on such clinical evidence, effective new cessation strategies targeted at youth should be developed. Rigorous enforcement of regulations governing e-cigarette production and marketing remains an urgent priority.

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