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Review article

A Practitioner's Guide to Electronic Cigarettes in the Adolescent Population



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A B S T R A C T

We present guidance on electronic nicotine delivery systems (ENDS) for health care professionals who care for adolescents. ENDS provide users with inhaled nicotine in an aerosolized mist. Popular forms of ENDS include e-cigarettes and vape-pens. ENDS range in disposability, customization, and price. Growth of ENDS usage has been particularly rapid in the adolescent population, surpassing that of conventional cigarettes in 2014. Despite surging use throughout the United States, little is known about the health risks posed by ENDS, especially in the vulnerable adolescent population. These products may potentiate nicotine addiction in adolescents and have been found to contain potentially harmful chemicals. The growth in these products may be driven by relaxed purchasing restrictions for minors, lack of advertising regulations, and youth friendly flavors. Taken together, ENDS represent a new and growing health risk to the adolescent population, one that health care professionals should address with their patients. We suggest a patient centered strategy to incorporate ENDS use into routine substance counseling.

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IMPLICATIONS AND CONTRIBUTION

The use of e-cigarettes by adolescents now exceeds that of conventional cigarettes. This article consolidates rapidly developing literature on the impact of e-cigarettes on adolescent health and provides practitioners with a best practices guide to e-cigarettes, including recommendations for discussing and treating the use of e-cigarettes among adolescent patients.

Electronic nicotine delivery systems (ENDS) are devices, relatively new to the consumer market, that provide users with inhaled nicotine via an aerosol mist. Examples of these devices include electronic cigarettes (e-cigarettes), vape pens, atomizers, vape pipes, hookah pens, e-hookahs, e-vaporizers, e-cigars, and e-pipes. Since their invention in 2004 and introduction in the

United States in 2007 [1], ENDS have rapidly gained in popularity, with sales rising from \$20 million in 2008 to more than \$1.5 billion in 2014 [2]. In 2014, use of ENDS in adolescents surpassed the use of conventional cigarettes: Recent use of ENDS was estimated to be 17% among 12th graders, whereas recent use of cigarettes was 14% [3].

Current assessments of the evidence suggest that ENDS may provide risk reduction compared with smoking conventional cigarettes [4]. However, the variability and unpredictability of the nicotine dose delivered by these devices, the potential adverse health effects of other substances in the nicotine solutions

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(i.e. “juice”), and the potential for these devices to act as a gateway to nicotine addiction are all causes for concern regarding the health risks of ENDS, particularly for adolescents.

Health care providers caring for adolescents and young adults should be aware of surging ENDS use in this population and, in a preventive health role, should include ENDS in substance use counseling. In this guide, we provide an overall strategy by describing ENDS, presenting current trends in use by adolescents, discussing how they affect adolescents, reviewing current regulations of ENDS as they pertain to adolescents, and presenting strategies for practitioners to discuss ENDS products with adolescents.

What Are Electronic Nicotine Delivery Systems?

ENDS contain three principal components—a fluid cartridge, an electronic heating element, and a battery. ENDS devices can be operated either manually, where the user activates the device by pressing a button, or automatically, where a flow sensor detects the air current and activates the device. When the device is activated, the heating element turns on and aerosolizes a solution, sending nicotine aerosol into the lungs. The solution contains a variety of chemicals, including nicotine at levels ranging from 0 to 36 mg/mL (a conventional cigarette contains .7–2.39 mg of inhaled nicotine) [5–9]. The solution also contains humectants such as propylene glycol and glycerin which generate the smoke-like appearance of the aerosol and simulate the effect of smoking [4]. The liquid may also contain a variety of flavors ranging from more common flavors such as tobacco, coffee, and mint to more unusual and youth-oriented flavors such as crème caramel, Italian cream soda, black cherry marshmallow, buttered popcorn, cotton candy, Kool Aid, Fruit Loops, and Hunger of Persephone (Figure 1A) [10]. Refill solutions are commonly sold in sizes ranging from 15–30 mL and range in price from \$0.50–1.00 per mL. A typical user will get 300–500 puffs per mL of fluid.

There are three major types of ENDS products. The first type is often described as a “ciga-like,” it is relatively small, resembles a cigarette, and comes in disposable and nondisposable forms. The nondisposable forms have a replaceable cartridge that contains the fluid and heating element that is sometimes referred to as a “cartomizer” (Figure 1B). The disposable products typically cost about \$10, while the reusable products cost between \$15–30. The second major class of ENDS products is referred to as vape pens or eGos. eGo, a brand initially created by Joytech, has become a common connection size between batteries and fluid cartridges referred to as “clearomizers.” These products are somewhat larger than the “ciga-like” products, are reusable, and offer the user the advantage of adding any fluid, including nicotine-free products, to the chamber for vaping. Vape pens can have a variety of additional features including variable voltage and replaceable tanks/atomizers (Figure 1C). Vape pens typically range in price from \$50–100. The last class of ENDS is referred to as advanced personal vaporizers, sometimes termed “mods” or AVPs (Figure 1D). These devices are highly customized to the users’ preferences and typically offer increased aerosol production. Consequently, these can be expensive, ranging in price from \$120–200.

In general, there is marked variability in aerosol production by devices [11]. Devices that are button activated have increased aerosol production relative to devices that are activated by air flow [12]. In addition, devices with larger, more powerful batteries can generate a hotter heating element and more aerosol [13].

Trends in Electronic Nicotine Delivery Systems Use Among Adolescents

A nationally representative study of high-school students found that in 2014, they used ENDS products more than conventional cigarettes. Current use (within the past 30 days) was at 17% among 12th-grade students, whereas conventional cigarette current use was 14% among 12th-grade students [3]. Furthermore, monthly use of e-cigarettes has grown exponentially among all high-school students from 1.5% in 2011 to 13.4% in 2014, whereas conventional cigarette use has steadily declined from 15.8% to 9.2% over the same period (Figure 2) [14–16]. Importantly, this survey data referred to ENDS as e-cigarettes, potentially narrowing the responses provided: the results may underestimate true prevalence of ENDS use [14–16]. Adolescents perceive ENDS to be a healthy alternative to conventional cigarettes: only 15% of students perceive ENDS use to pose a great risk to their health, yet 62% believe that smoking a pack of conventional cigarettes poses a great risk to their health [3]. In addition to perceived safety, a qualitative study found that students are motivated to use ENDS because they view ENDS as easy to consume and conceal, accessible, and more aesthetically pleasing than conventional cigarettes [17].

Of particular concern is that increased popularity of ENDS among adolescents may result in an increase in cigarette use because of nicotine addiction and/or renormalization of smoking behaviors. Rates of dual use (ENDS and cigarettes) are high, with 93%–96% of ENDS-using students having smoked a conventional cigarette at some point [3]. Rates of current dual use were assessed in a 2012 survey; these somewhat dated results indicated that about 50% of current ENDS users were also using conventional cigarettes (as defined as use within the last 30 days) [18]. Furthermore, recent survey data from Poland indicate that current dual use (within the last 30 days) has increased from 4% in 2010–2011 to 22% in 2013–2014 of all surveyed students aged 15–19 years (tobacco use is far more common in Poland than the United States) [19]. Recent data from a longitudinal cohort study shows that among high school students that were ever ENDS users 25% went on to be ever conventional tobacco product users, compared with 9% in the population that had never used an ENDS. When controlled for known smoking risk factors, ever ENDS use was positively associated with subsequent conventional tobacco product use (OR, 2.73 [95% CI, 2.00–3.73]). [20] Finally, studies have found that ever ENDS use among adolescents was associated with both an increased openness and greater intention to smoke conventional cigarettes. [21,22] These data raise the concern that ENDS may be an entry point to cigarette use and may act to perpetuate cigarette use.

Risks of Electronic Nicotine Delivery Systems

As the name suggests, the purpose of ENDS is to deliver nicotine—an addictive and potentially toxic exposure—to the user. Nicotine has deleterious effects on the developing brain, harming neurodevelopment in utero and may have effects on brain development in adolescence [23,24]. Adolescence is a critical period of brain development with normal neurobiological changes that allow for increased risk-taking and heightened reactivity to short-term rewards rather than long-term goals. In animal studies, nicotine has been associated with cellular damage as well as acute and persistent changes in different neurobiological pathways within the developing adolescent brain [24].



Figure 1. (A) Sample ENDS refill solutions with flavors tobacco, crème caramel, black cherry marshmallow, and Hunger of Persephone. (B) A reusable e-cigarette commonly described as a “ciga-like” product. (C) A vape pen, also referred to as an eGo. (D) An advanced personal vaporizer, referred to as an Advanced Personal Vaporizer or mod.

Behaviorally, adolescents have been found to be more sensitive to nicotine and more likely to demonstrate dependence than their adult counterparts even with relatively low amounts of nicotine exposure and more likely to have continued use into adulthood [23,24]. In fact, 88% of adults who remain daily smokers started before the age of 18 years [23]. Furthermore, evidence suggests that nicotine usage precedes use of other drugs, such as marijuana [23,25]. It is perhaps not surprising then that a recent cross-sectional study found that adolescents in the United Kingdom who abused alcohol had much higher rate of ENDS usage, although more research is needed to establish the

temporality and directionality of this relationship [26]. Unlike cigarette products, ENDS typically advertise a specific amount of nicotine. However, the labeling is often incorrect, and ENDS have been found to contain nicotine levels ranging by as much as 50% from the declared concentration, making it difficult to control the amount of actual nicotine consumption when using ENDS. Furthermore, nicotine per puff within the same device may vary by as much as a 40% [27]. In addition, multiple studies have found that ENDS that are touted as nicotine free often contain nicotine [4]. Finally, refill solutions often come in cartridges with high nicotine content, which can pose a risk for adolescents when

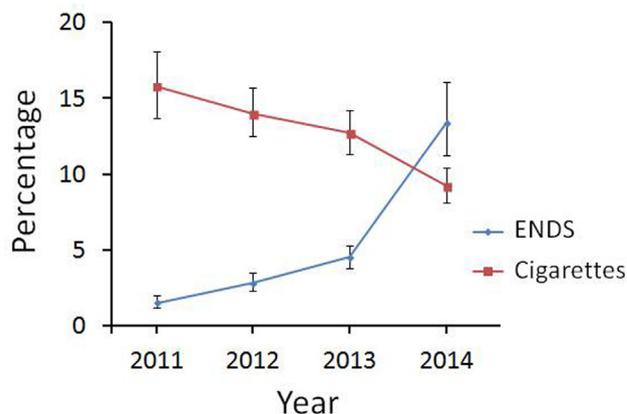


Figure 2. Trends in use e-cigarettes (blue diamond, notably the data were obtained querying about e-cigarette use, not ENDS use in general) and conventional cigarettes (red square) among high-school students, defined as ≥ 1 use within last 30 days. Data are presented from the National Youth Tobacco Survey [14–16]. Error bars represent 95% confidence interval

refilling ENDS products or for young children who may accidentally ingest or handle the solution. The high concentrations can easily reach toxic doses, as the nicotine can be absorbed orally or transdermally [28]. Data from Texas show that poison control centers have seen a rapid rise in ENDS fluid exposures, from two exposures in 2009 to 123 in 2013 [29].

ENDS manufacturers often advocate that their products are healthier than conventional cigarettes and contain only water, nicotine, glycerin, propylene glycol, and flavoring; [30] this is reflected in the perception among adolescents that ENDS products pose little threat to their health [3]. These claims, however, are misleading as chemists have found varying levels of heavy metals in the vapor, including chromium, nickel, tin, silver, cadmium, mercury, and aluminum [4]. Carcinogens have also been identified; tobacco-specific nitrosamines have been detected in the vapor of some devices, and formaldehyde and acetaldehyde have been detected consistently, especially when the heating element is operated at high voltage [4,31,32]. Some ENDS solutions contain harmful flavoring molecules, diacetyl and acetyl propionyl, used to add a buttery taste to the vapor and are known to cause bronchiolitis obliterans. These chemicals have been demonstrated to be present in higher concentrations in ENDS than is recommended by the National Institute of Occupational Safety and Health [33]. Although all these toxins are typically present in ENDS at lower concentration than conventional cigarettes, they may still pose a risk to the user.

ENDS also contain potentially harmful compounds that are not found in tobacco products. One of the humectants that allows formation of visible vapor in ENDS products, propylene glycol, is known to be a respiratory irritant. Glycols are known to have hygroscopic properties that draw moisture out of mucus membranes. Glycols are commonly used to create artificial fog, an entity shown to contribute to produce small decreases in forced expiratory volume in 1 second/forced vital capacity ratios in exposed individuals [34].

In addition to direct effects on the user, there may be risks because of secondhand “vapor” from ENDS, although it is much less understood and likely to be less toxic than conventional cigarettes. A recent study showed that ENDS increased environmental levels of nicotine, 1,2-propanediol, glycerin, particulate matter and aluminum [35]. One group has found that

exposure to secondhand vapor and secondhand smoke generates equivalent blood levels of nicotine metabolite cotinine, whereas another has found that with ENDS use, environmental levels of nicotine are present but significantly reduced when compared with that of conventional cigarettes [36,37]. Although the health effects of secondhand vapor have yet to firmly established, it seems likely that these secondhand effects are less toxic than the effects of conventional cigarette use (similar to direct ENDS use being less toxic than cigarette use).

Although more research is needed to truly understand the risks that chronic ENDS use poses to adolescent health, ENDS are unpredictable in their nicotine content, contain other chemicals known to be deleterious to health, and may initiate nicotine addiction and predispose to the use of traditional nicotine and tobacco products.

Current Regulation

Although regulated by the Food and Drug Administration (FDA) as a tobacco product, regulations designed to discourage use of ENDS among adolescents in the United States are relatively weak compared with those of traditional tobacco products (Table 1). States only began enacting age restrictions for ENDS sales to minors in 2010, and as of November, 2014, 40 states have prohibited sales of ENDS to minors [38]. A national age purchasing restriction has been proposed by the Food and Drug Administration’s Center for Tobacco Products but has not yet been approved. Although the effect of these bans on youth purchases of ENDS has not been directly assessed, the bans have been associated with an increase in conventional cigarette usage by infrequent adolescent smokers [39,40]. This suggests that simply banning the legal purchase of ENDS products among adolescents may not be a sufficient solution, and comprehensive tobacco control may be necessary to discourage use of all forms of tobacco among adolescents. Furthermore, adolescents may be able to avoid ENDS legal purchase age laws by using the Internet to buy ENDS, a strategy that minors employed with little resistance in one study [41].

Unlike cigarettes, in which flavors are limited to menthol, there are no flavor restrictions on ENDS products. This has resulted in the creation of many youth friendly flavors, such as milk chocolate, cola, and cotton candy. At this point, more research is needed to determine the effect of these flavors on adolescent ENDS usage

Table 1
Summary of current regulations

| Electronic nicotine delivery systems | Conventional cigarettes |
|---|---|
| Sales to minors restricted in 40 states; Food and Drug Administration Center for Tobacco Products has proposed a national age purchasing restriction ban. | Sales to minors are restricted. |
| There are no restrictions on product flavorings. | Flavoring is restricted to menthol. |
| Advertising remains unrestricted. | Advertising is heavily regulated. |
| Taxed in only two states—Minnesota (at a rate of 95% of cost of the product) ^a and North Carolina (at a rate of \$.05 per milliliter of fluid). ^b | Highly taxes—\$1.01 federal tax and state taxes ranging from \$.17 in Missouri to \$4.35 in New York ^c |

^a E-cigarettes. Published 2014. <http://www.revenue.state.mn.us/businesses/tobacco/Pages/e-Cig.aspx>. Accessed July 3, 2015.

^b Maguire M. North Carolina lawmakers adopt tax on electronic cigarettes. Reuters 2014.

^c Walker and Orzechowski. The Tax Burden on Tobacco. 2014; 49.

[28]. Between the rapid growth in advertising spending and flavors that are tailored to youth, adolescents may be particularly vulnerable to ENDS use and resultant nicotine addiction.

Unlike cigarettes where advertising bans on television have been in place since 1971 [42], there are no controls on how ENDS manufacturers may market their products, allowing promotion of their product through advertisements on television, the Internet, and social media and other forms of media [28,43]. Advertising expenditures for ENDS has tripled from \$6.4 million in 2011 to \$18.3 million in 2012 [44].

Perhaps owing to the ability of adolescents to purchase ENDS, the broad availability of flavorings, and the unregulated advertising through mediums often used by adolescents, it is unsurprising that American youth use ENDS in high numbers.

Tips for Addressing Electronic Nicotine Delivery Systems Use

It is critical that providers be aware of adolescent ENDS use because of the health risks it presents to the individual. The adolescent health care visit is uniquely capable of identifying and addressing this issue. We suggest that practitioners integrate the following three steps into their routine substance use counseling provided to adolescents and preteens: (1) screen patients for ENDS use; (2) identify and correct misconceptions about ENDS products; and (3) counsel patients with regard to cessation.

Screening for ENDS use can be integrated into routine substance use screening, following the well-known guidelines used in such screening, including establishing and ensuring confidentiality, querying patient knowledge about ENDS products, and peer usage. Similar techniques have been found to be effective in other forms of substance use counseling in adolescents [45] and should be incorporated into provider discussions regarding ENDS use.

When asking about ENDS, recognize that there are hundreds of ENDS products that go by different names such that it may be best to inquire about the use of a number of different devices, such as, e-cigarettes, atomizers, vape pens, vape pipes, hookah pens, e-hookahs, e-vaporizers, e-cigars, or e-pipes.

Quantifying use may also be challenging given the diversity of ENDS products and the variability in nicotine concentration and delivery [4]. Information that can help quantify usage includes the brand of device used, frequency of use, concentration of nicotine used, and volume of fluid used per day.

In addition to inquiring about use, it is important to screen for risk factors that predispose to ENDS use. Although not yet evidence based, it is reasonable to equate the risk factors for ENDS use with those associated with conventional cigarette use, for example, parental smoking, peer smoking, falsely increased perception of prevalence of smoking in peer group, experimentation with tobacco products, poor performance in school, and dysphoria [46].

Whether ENDS use has been identified, a practitioner should attempt to identify and address misconceptions about ENDS products. Adolescents may perceive ENDS to be safer than cigarettes. Although this perception is likely true, health data are still emerging. The probable relative risk reduction of ENDS use is worth mentioning to adolescents, but it is important to advise against their use as ENDS exposure is still harmful compared with abstinence, particularly, as mentioned earlier, in light of the exposure to nicotine, variability of nicotine dosing, and effects of other substances in the nicotine solutions. Teens may also perceive that most of their peers are using ENDS products. In

such situations, it would be important to clarify that in fact only a minority of adolescents use ENDS (9%–17% according to the Monitoring the Future study) [3]. It is especially important to educate current ENDS users about these products by emphasizing that ENDS are in fact a tobacco product, they provide users with the highly addictive substance nicotine, the vapor does not contain just water and nicotine, the risks to their health are not yet fully understood, and a minority of teens use such products.

ENDS are widely perceived as a smoking cessation or reduction aid, and as such, providers should be aware of the current evidence to support this claim. A recent Cochrane review found that in the adult population, there is only low-level evidence to suggest that nicotine-containing ENDS are effective smoking cessation tools when compared with nicotine-free ENDS. Most of their findings are based on two randomized controlled trials [47]. A number of randomized controlled trials are currently underway, and this story will continue to develop [47]. The use of ENDS as a smoking cessation tool for adolescents has yet to be investigated. Currently, the sale of established over the counter nicotine replacement therapies (NRT) to minors is banned by the FDA [48]; however, studies show that this ban has little effect on adolescent access to NRT [49]. The clinical use of NRT in adolescent populations is controversial with approximately 50% of pediatricians believing it safe to use in practice [50].

When counseling patients with regard to cessation of ENDS products, we recommend using an established approach for conventional cigarette counseling. The generally accepted approach to smoking cessation counseling centers on the “5 A” model. In this model, patients are first *asked* if they smoke. If they do smoke, they are *advised* to stop smoking. The advice is followed by *assessing* if the patient is ready to make an attempt to quit. If the patient wants to quit, the provider should *assist* by offering support, helping the patient set a quit date, referring to quit lines, or offering medication. Last, the provider should not forget to *arrange* for a follow-up appointment or phone call within 1 week of the quit date [51]. In addition, for adolescents, it has been recommended that pediatricians add “an extra A” and offer *anticipatory* guidance, by screening for risk factors and advocating in advance for abstinence from tobacco and nicotine [46].

ENDS usage is rapidly growing in America and is now more prevalent than conventional cigarette usage in adolescent populations. These products represent a new and only partially understood health risk to adolescent patients. Pediatricians and other practitioners have the unique power and responsibility to advocate for their patients’ health by screening for, offering education on, and promoting cessation of ENDS use.

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