Exposure Calls to U. S. Poison Centers Involving Electronic Cigarettes and Conventional Cigarettes—September 2010–December 2014

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Abstract

Introduction E-cigarette use is increasing, and the long-term impact on public health is unclear. We described the acute adverse health effects from e-cigarette exposures reported to U.S. poison centers.

Methods We compared monthly counts and demographic, exposure, and health effects data of calls about e-cigarettes and conventional cigarettes made to poison centers from September 2010 through December 2014.

Results Monthly e-cigarette calls increased from 1 in September 2010, peaked at 401 in April 2014, and declined to 295 in December 2014. Monthly conventional cigarette calls during the same period ranged from 302 to 514. E-cigarette calls were more likely than conventional cigarette calls to report adverse health effects, including vomiting, eye irritation, and nausea. Five e-cigarette calls reported major health effects, such as respiratory failure, and there were two deaths associated with e-cigarette calls.

Conclusion E-cigarette calls to U.S. poison centers increased over the study period, and were more likely than conventional

cigarettes to report adverse health effects. It is important for health care providers and the public to be aware of potential acute health effects from e-cigarettes. Developing strategies to monitor and prevent poisonings from these novel devices is critical.

Keywords Electronic nicotine delivery systems · Poison centers · Health effects

Introduction

Electronic nicotine delivery systems, such as electronic cigarettes (e-cigarettes), e-cigars, and e-hookahs, are battery-operated products designed to deliver nicotine, flavor (e.g., fruit, bubble gum, chocolate), and other chemicals to the user in an aerosol [1, 2]. E-cigarette use has increased in the USA since being introduced in 2007, particularly among youth. The percentage of U. S. high school students who reported using an e-cigarette on ≥ 1 day during the past 30 days increased from 1.5 % in 2011 to 13.4 % in 2014 [3, 4]. In 2014, 17.1 % of all U. S. 12th graders reported using an e-cigarette in the past 30 days [5]. In addition, the percentage of U. S. adults who reported ever using an e-cigarette increased from 3.3 % in 2010 to 8.5 % in 2013, with nearly 20.4 million U. S. adults reporting that they had tried e-cigarettes in 2013 [6].

With this increase in use of electronic nicotine delivery systems, the public health community has raised potential safety concerns, including the high concentration of nicotine in some e-liquids, lack of information on other chemicals in the e-liquid, and absence of child-resistant containers [7]. An analysis of calls to U. S. poison centers documented an increase in the number of monthly calls reporting an exposure to an e-cigarette or e-liquid from 1 in September 2010 to 215 in February 2014 [8].

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However, the report did not explore routes of exposure in different age groups and the acute adverse health effects from these exposures. Therefore, we extended the investigation through December 2014 to provide details about the exposures and to better describe the acute adverse health effects.

Methods

Exposure Call Analysis

In 2014, the 56 poison centers in the USA received a total of 2.2 million calls about human exposure to various substances; not all of these exposure calls resulted in adverse health effects [9]. Data from each call were uploaded to the National Poison Data System (NPDS), which serves as a national data repository and surveillance system. Poison center staff members assign a unique numerical code based on a caller's description of the exposure, substance, or product. These codes are used to classify calls in NPDS. The American Association of Poison Control Centers released codes for e-cigarettes and e-liquid in January 2010. The first call to use this code was reported in September 2010. Therefore, we searched for e-cigarette calls to poison centers from September 1, 2010, through December 31, 2014. For the purposes of this analysis, we defined e-cigarette calls as those involving exposures to either the device or the e-liquid.

In addition to e-cigarettes, we also searched NPDS for calls coded for human exposure involving conventional cigarettes. We evaluated conventional cigarettes to provide a comparison to an established, conventional product with known toxicity. We defined conventional tobacco cigarette calls as those involving exposures to conventional cigarettes, excluding cigarette butts to allow for comparisons between products. We subsequently performed a sensitivity analysis by including cigarette butts with the conventional cigarette calls. We excluded calls involving exposure to multiple substances (e.g., ethanol and conventional cigarettes) because it can be difficult to discern which health effects are due to which exposure when there are multiple substances involved.

For e-cigarettes and conventional cigarettes, we reported monthly and total call counts, as well as the proportions of the total number of calls for each exposure by sex and age group (0–5, 6–10, 11–19, and ≥ 20 years) of the exposed person, location where the call originated, and whether referral to a health care facility was recommended by poison center staff for calls originating outside of a health care facility. Location where the call originated was dichotomized into calls from health care workers at a health care facility and calls from non-health care workers (e.g., exposed person, family member) outside of a health care facility. We also noted routes of exposure (e.g., ingestion, inhalation/nasal), count and type of adverse health effects (e.g., nausea, vomiting, cough), affected body system

(e.g., gastrointestinal, neurological), and severity of health effects. Severity was categorized as no effect, minor effect (e.g., drowsiness, first-degree burns, transient cough), moderate effect (e.g., isolated brief seizure, gastrointestinal symptoms causing dehydration), major effect (e.g., respiratory failure requiring intubation, repeated seizures, coma), and death [9].

For categorical variables, we compared e-cigarette and conventional cigarette calls using chi-squared or Fisher's exact tests in SAS version 9.3 and defined statistical significance as $P < .05$. Given anticipated differences based on age, we stratified route of exposure, health effect severity, and affected body system by age group. This analysis was deemed by the Center for Disease Control and Prevention's National Center for Environmental Health, Office of Science, to not constitute human subjects research as it involved de-identified, previously collected data.

Case Note Analysis

Poison center case notes include free-text narratives written by poison center staff for each call. However, those narratives are not uploaded to NPDS and therefore are not available in NPDS. We obtained the case notes for e-cigarette calls with a medical outcome of "moderate" or "major" from September 2010 through April 2014. Two of the co-authors reviewed the free-text portion of each case note and abstracted data on pre-defined topics involving the exposure. Those topics included concentration of the nicotine in the e-liquid, clear labeling of the nicotine concentration, product name, and whether exposure was to the e-cigarette device or e-liquid. We calculated Cohen's kappa coefficient using SAS version 9.3 to assess inter-rater reliability.

Results

Exposure Call Analysis

From September 1, 2010, through December 31, 2014, poison centers reported 5970 e-cigarette calls and 21,106 tobacco cigarette calls from across the USA, the District of Columbia, and U. S. territories. We excluded 163 e-cigarette calls (2.7 % of all e-cigarette calls) and 734 conventional cigarette calls (3.6 % of all conventional cigarette calls) involving exposure to multiple substances, such as ethanol and conventional cigarettes, and 17 calls assigned both a conventional cigarette code and an e-cigarette code. The remaining 5807 e-cigarette calls included 5085 calls involving exposure to the e-cigarette device and 722 calls involving exposure to the e-liquid alone.

When we analyzed calls by month, e-cigarette calls increased from one in September 2010 to a peak of 401 in April 2014, followed by a decline to 295 in December 2014 (Fig. 1). Conventional cigarette calls ranged from 302 to 514

Fig. 1 Number of e-cigarette and cigarette calls reported to US poison centers, by month, September 1, 2010–December 31, 2014

per month, with more calls reported during summer months. Just over half of e-cigarette and conventional cigarette exposures involved males (53.9 and 54.1 %, respectively) (Table 1). The median age of exposed persons in e-cigarette calls was 2 years (range 1 month–84 years) and the median

age for conventional cigarette calls was 1 year (range 1 month–97 years). E-cigarette exposures were mostly among the 0–5-year age group ($n = 3341$; 58.0 %) and the ≥ 20 -year age group ($n = 2001$; 34.7 %), whereas conventional cigarette exposures were primarily among the 0–5-year age group

Table 1 Characteristics of e-cigarette and cigarette calls to US poison centers, September 1, 2010–December 31, 2014

Variable	E-cigarette calls no. (%)	Cigarette calls no. (%)	<i>P</i> value
Sex (<i>n</i> = 26,095)			
Female	2668 (46.1)	9326 (45.9)	.7656
Male	3115 (53.9)	10,986 (54.1)	
Age (years) (<i>n</i> = 26,071)			
0–5	3341 (58.0)	19,298 (95.0)	<.0001
6–10	108 (1.9)	104 (0.5)	
11–19	314 (5.5)	234 (1.2)	
≥20	2001 (34.7)	671 (3.3)	
Location of caller (<i>n</i> = 25,028)			
Health care facility	805 (14.7)	1163 (6.0)	<.0001
Non-health care facility	4665 (85.3)	18,395 (94.1)	
Exposure route (<i>n</i> = 26,134)			
Ingestion	3808 (65.8)	19,699 (96.8)	<.0001
Inhalation/nasal	636 (11.0)	379 (1.9)	
Eye	498 (8.6)	16 (0.1)	
Multiple routes	462 (8)	218 (1.1)	
Skin	376 (6.5)	26 (0.1)	
Ear	9 (0.2)	0 (0)	
Parenteral	3 (0.05)	2 (0.01)	
Rectal	0 (0)	2 (0.01)	

Excludes missing data

($n = 19,298$; 95.0 %; Table 1). A greater proportion of e-cigarette calls ($n = 805$; 14.7 %) than conventional cigarette calls ($n = 1163$; 6.0 %) came from health care facilities ($P < .0001$). Among calls originating outside of health care facilities, the exposed person in e-cigarette calls compared to conventional cigarette calls was more likely to be referred to a health care facility ($n = 946$; 20.3 % versus $n = 1913$; 10.4 %) or already en route to a health care facility ($n = 194$; 4.2 % versus $n = 364$; 2.0 %; $P < .0001$).

Compared with conventional cigarette exposures, e-cigarette exposures were less likely to be reported as ingestions and more likely to be reported as another route, such as inhalation/nasal (Table 1). When stratified by age, the majority of exposures in the 0–5-year age group for e-cigarettes and for conventional cigarettes occurred through ingestion ($n = 2706$; 81.2 % and $n = 19,056$; 98.8 %, respectively). Compared with the 0–5-year age group, the proportion of calls reporting ingestion for e-cigarettes and for cigarettes was lower in the older age groups. Older age groups had higher percentages of e-cigarette and of conventional cigarette calls with inhalational/nasal exposure than did the 0–5-year age group (Table 2).

A greater proportion of e-cigarette calls ($n = 3403$; 59.1 %) had sufficient information to determine the medical outcome than tobacco cigarette calls ($n = 10,642$; 52.7 %) ($P < .0001$). Among these 14,045 calls, e-cigarette calls were more likely to report an adverse health effect ($n = 1726$; 50.7 %) than conventional cigarette calls ($n = 3834$; 36.0 %) ($P < .0001$).

For the calls with a reported adverse health effect, e-cigarette calls were more likely to be classified as involving a moderate effect, such as a seizure or vomiting causing dehydration (11.7 versus 5.9 %), or major effect, such as a respiratory failure (0.3 versus 0.1 %), than conventional cigarette calls ($P < .0001$). Similarly, in the 0–5-year age group, e-cigarette calls were more likely to be classified as having a moderate effect (7.4 versus 4.8 %) or major effect (0.4 versus 0.03 %) than conventional cigarette calls (Table 3, $P = .0003$). However, in the ≥ 20 -year age group, conventional cigarette calls were more likely to be classified as a moderate effect (25.2 versus 15.5 %) or major effect (1.3 versus 0.3 %) and less likely to be classified as a minor effect, such as a transient cough (73.5 versus 84.2 %) than e-cigarette calls ($P = .003$; Table 3).

Of the two adults reported to have major health effects in e-cigarette calls, one had hypertension, drowsiness, and seizure, and one had confusion, dystonia, hallucinations, electrolyte abnormality, and renal failure. Of the three children reported to have major health effects in e-cigarette calls, two had cyanosis and respiratory arrest, and one had nausea, vomiting, seizure, and coma. Among the e-cigarette calls, two deaths were reported to poison centers—one death from ingestion of e-liquid in the 0–5-year age group and one suicide death from parenteral injection of e-liquid in the ≥ 20 -year age group. The health effects reported in the adult case included dysrhythmia, hypotension, tachycardia, fever, acidosis, aspartate aminotransferase (AST) and alanine aminotransferase (ALT) levels between 100

Table 2 Exposure route in e-cigarette and cigarette calls to U.S. poison centers, by age group, September 1, 2010–December 31, 2014

Age (years)	Route	E-cigarette calls no. (%)	Cigarette calls no. (%)	<i>P</i> value
0–5 ($n = 22,618$)	Ingestion	2706 (81.2)	19,056 (98.8)	<.0001
	Inhalation/nasal	117 (3.5)	9 (0.05)	
	Ocular	60 (1.8)	6 (0.03)	
	Multiple	338 (10.1)	203 (1.1)	
	Dermal	111 (3.3)	12 (0.06)	
6–10 ($n = 209$)	Ingestion	55 (52.4)	99 (95.2)	<.0001
	Inhalation/nasal	27 (25.7)	4 (3.9)	
	Ocular	10 (9.5)	1 (1)	
	Multiple	3 (2.9)	0 (0)	
	Dermal	10 (9.5)	0 (0)	
11–19 ($n = 546$)	Ingestion	159 (50.8)	149 (64)	<.0001
	Inhalation/nasal	84 (26.8)	80 (34.3)	
	Ocular	34 (10.9)	2 (0.9)	
	Multiple	17 (5.4)	1 (0.4)	
	Dermal	19 (6.1)	1 (0.4)	
≥ 20 ($n = 2656$)	Ingestion	875 (44)	357 (53.5)	<.0001
	Inhalation/nasal	392 (19.7)	276 (41.4)	
	Ocular	389 (19.6)	7 (1.1)	
	Multiple	103 (5.2)	14 (2.1)	
	Dermal	230 (11.6)	13 (2)	

Excludes missing data

Table 3 Severity of health effect in e-cigarette and cigarette calls to U.S. poison centers by age group, September 1, 2010–December 31, 2014

Age (years)	Effect category	E-cigarette calls no. (%)	Cigarette calls no. (%)	P value
0–5 (<i>n</i> = 4435)	Minor	776 (92.3)	3422 (95.2)	.0003
	Moderate	62 (7.4)	171 (4.8)	
	Major	3 (0.4)	1 (0.03)	
6–10 (<i>n</i> = 54)	Minor	30 (91)	20 (95.2)	–
	Moderate	3 (9.1)	1 (4.8)	
	Major	0 (0)	0 (0)	
11–19 (<i>n</i> = 179)	Minor	96 (81.4)	46 (75.4)	–
	Moderate	22 (18.6)	15 (24.6)	
	Major	0 (0)	0 (0)	
≥20 (<i>n</i> = 873)	Minor	608 (84.2)	111 (73.5)	.003
	Moderate	112 (15.5)	38 (25.2)	
	Major	2 (0.3)	2 (1.3)	

Limited to calls in which a minor, moderate, or major health effect was reported. Excludes missing data

and 1000 international units per liter (IU/L), seizures, and cardiorespiratory arrest. The health effects reported in the child were asystole and cardiac arrest.

The sensitivity analysis including cigarette butt calls showed that there were 3989 total cigarette butt calls, with a monthly median of 76.5 calls (range 54–111). Inclusion of cigarette butt calls did not significantly alter the findings between e-cigarette and conventional cigarette calls for sex, age, proportion of calls originating from a health care facility, route of exposure, or report of an acute adverse health effect.

For the 1726 e-cigarette calls reporting an adverse health effect, the ten most common effects were vomiting (40.4 %), eye irritation or pain (20.3 %), nausea (16.8 %), red eye or conjunctivitis (10.5 %), dizziness (7.5 %), tachycardia (7.1 %), drowsiness (7.1 %), agitation (6.3 %), headache (4.8 %), and cough (4.5 %). Table 4 shows the most common adverse health effects by exposure route for the e-cigarette calls. For the 3835 conventional cigarette calls reporting an adverse health effect, the ten most common effects were vomiting (80.0 %), nausea (9.2 %), drowsiness (7.8 %), cough (7.2 %), agitation (6.6 %), pallor (3.0 %), tachycardia (2.5 %), diaphoresis (1.5 %), dizziness (1.5 %), and diarrhea (1.4 %). Table 5 shows the signs and symptoms aggregated by body system.

Case Note Analysis

From the 128 e-cigarette calls classified as moderate or major effect from September 2010 through April 2014, we obtained case notes for 113 moderate effect calls and 4 major effect calls. Of these 117 case notes, 68 (58.1 %) exposures were related to the e-cigarette device, 46 (39.3 %) to the e-liquid from a refill bottle, and 1 (0.9 %) to nicotine gel, and 2 (1.7 %) exposure sources were not documented. A product name for the e-cigarette device or e-liquid was documented for 22 (18.8 %) case notes; no single product name was documented in multiple case notes. The nicotine concentration of e-liquid was documented in 24 (20.5 %) of the 117 case notes, with a

variety of reported concentrations: 6 mg/50 mL, 16 mg/15 mL, 16–24 mg/1 cartridge, 24 mg/1 drop, 24 mg/1 mL, 24 mg/1 oz, 24 mg/1 e-cigarette, 100 mg/1 mL, and 1.4 and 100 %. For two of these e-cigarette calls, poison center staff had to locate the nicotine concentration online as part of

Table 4 Most common health effect in e-cigarette calls to U.S. poison centers by exposure route, September 1, 2010–December 31, 2014

Route	Health effect	No. (%) ^a
Ingestion	Vomiting	609 (60.2)
	Nausea	172 (17.0)
	Drowsy	109 (10.8)
	Tachycardia	85 (8.4)
	Agitated	70 (6.9)
Inhalation/nasal	Nausea	78 (37.9)
	Vomiting	46 (22.3)
	Dizziness	43 (20.9)
	Agitated	23 (11.2)
Ocular	Headache	22 (10.7)
	Eye irritation or pain	286 (93.5)
	Red eye or conjunctivitis	152 (49.7)
	Blurred vision	21 (6.9)
	Headache	6 (2.0)
Multiple routes	Corneal abrasion	6 (2.0)
	Eye irritation or pain	35 (27.6)
	Vomiting	29 (22.8)
	Red eye or conjunctivitis	20 (15.8)
	Nausea	14 (11.0)
Dermal	Cough	9 (7.1)
	Nausea	20 (29.9)
	Dizziness	15 (22.4)
	Vomiting	11 (16.4)
	Headache	9 (13.4)
	Tachycardia	7 (10.5)

^a Percentages do not sum to 100

Table 5 Affected body systems in e-cigarette and cigarette calls to U.S. poison centers, September 1, 2010–December 31, 2014

Body system	E-cigarette call no. (%) <i>n</i> = 1726	Cigarette call no. (%) <i>n</i> = 3834	<i>P</i> value
Gastrointestinal	962 (55.7)	3214 (83.8)	<0.0001
Head, ears, eyes, nose, and throat	383 (22.2)	33 (0.9)	<0.0001
Neurological	342 (19.8)	364 (9.5)	<0.0001
Cardiovascular	178 (10.3)	123 (3.2)	<0.0001
Constitutional ^a	180 (10.4)	408 (10.6)	0.8112
Respiratory	160 (9.3)	319 (8.3)	0.2429
Dermatological	135 (7.8)	96 (2.5)	<0.0001
Musculoskeletal	13 (0.8)	15 (0.4)	0.0777
Metabolic	10 (0.6)	3 (0.1)	0.0008
Hematological	1 (0.1)	5 (0.1)	0.6730
Genitourinary	1 (0.1)	0 (0)	0.3104

Ordered by frequency of body systems in the e-cigarette exposed group. Excludes missing data

^a Includes general signs and symptoms, such as fever, drowsiness, and pallor

assessing the exposure. In three additional calls, poison center staffs were unable to determine the concentration of the nicotine for e-liquid that lacked clear labeling. In nine calls, exposed persons reported that the e-cigarette device leaked; six leaks resulted in oral/ingestion exposures, one resulted in skin exposure, and two did not specify the route of exposure. In five calls, exposed persons put e-liquid in their eyes instead of their regular eye drops, reportedly resulting in health effects such as blurred vision, miosis, eye irritation or pain, red eye or conjunctivitis, and corneal abrasion. In one call, an adult gave the e-liquid to an infant by mouth, mistaking it for the infant's regular medication; this infant reportedly had tachycardia and respiratory depression. Agreement between the two raters was high, with kappa values >0.85 for all variables reported.

Discussion

We documented that monthly e-cigarette calls to poison centers increased overall from September 2010 through December 2014. Conventional cigarette calls outnumbered e-cigarette calls in most months and were higher in the summer months and lower in the winter months, a seasonal pattern also seen in overall call volume to U. S. poison centers [9]. In 2014, U. S. e-cigarette sales totaled an estimated \$2.8 billion, whereas annual conventional cigarette sales were \$80 billion [10, 11]. Despite estimated e-cigarette sales equivalent to only 3.5 % of conventional cigarette sales, e-cigarettes accounted for 44 % of combined monthly e-cigarette and conventional cigarette calls in December 2014.

Multiple reasons might account for the sharp increase in monthly e-cigarette calls in early 2013. Increasing sales of electronic nicotine delivery systems likely contributed to this trend, with sales of disposable e-cigarettes, starter kits, and cartridge

refills at convenience stores and food, drug, and mass merchandisers increasing by 150 % from 2012 to 2013 [12]. In addition, media reports might influence poison center call volume [13]. Several media reports highlighted potential adverse health effects of e-cigarettes in April and May 2014, and April 2014 had the greatest number of monthly calls during the study period [8, 14].

Most conventional cigarette calls (95.0 %) involved children aged ≤5 years, whereas less than two thirds (58.0 %) of e-cigarette calls involved children aged ≤5 years. Compared with tobacco cigarette calls, the age distribution of e-cigarette calls was closer to the age distribution of the total 2.2 million exposure calls to poison centers in 2013, in which nearly half of calls (48 %) involved children aged ≤5 years [9]. One of the public health concerns regarding electronic nicotine delivery systems is the potential for children to ingest nicotine-containing e-liquid [7]. Colorful packaging and alluring flavors, the high level of nicotine in some e-liquids, adults mistaking e-liquid for children's medication, and the lack of child-resistant containers all might contribute to the potential increased risk for exposure among children. The large percentage of adults involved in e-cigarette calls might reflect that e-cigarettes are relatively novel devices with many inexperienced users and that users may be exposed to nicotine and other chemicals via multiple routes (e.g., inhalation, ingestion, ocular, dermal). In comparison, conventional cigarettes are established products with experienced users who may be more accustomed to acute health effects from cigarette use, such as coughing and throat irritation, and who might be less likely to report such effects to poison centers.

Routes of exposure also differed in e-cigarette and conventional cigarette calls. For example, eye exposures were reported in 8.6 % of e-cigarette calls and 0.1 % of conventional cigarette calls. As described in the case notes, some of the e-cigarette eye exposures occurred when exposed persons mistakenly applied e-liquid to their eyes instead of eye medication, resulting mostly

in minor, likely transient effects, such as blurry vision, or moderate effects, such as corneal abrasion. Lack of clear labeling might have been a contributing factor to these eye exposures, as well as the oral exposure in which an adult mistakenly gave e-liquid to an infant by mouth.

Although the majority of e-cigarette calls (88.1 %) and conventional cigarette calls (94.1 %) reporting health effects were classified as involving a minor effect, multiple factors indicate that e-cigarette exposures might have been more severe than conventional cigarette exposures. A greater percentage of e-cigarette calls originated from a health care facility; patients who present to a health care facility for evaluation may have more severe health effects than persons who call the poison center from home or who decide to not seek care. E-cigarette calls were also more likely to be referred to a health care facility, report an adverse health effect, and be classified as having a moderate or major effect. There have been reports of suicide deaths in the USA associated with e-liquid, including an adult who developed cardiac arrest and seizures following intravenous injection of e-liquid and an adult who developed cardiac arrest following intentional ingestion of e-liquid and ethanol [15, 16]. In addition, there is a case report from Germany of a suicide attempt by ingestion of e-liquid in which the patient developed vomiting, dizziness, tachycardia, and hypertension before recovering [17].

The range of nicotine concentration among e-liquid products on the market varies considerably (e.g., 0, 12, 24 mg/mL). Some e-liquid solutions that are meant to be diluted contain up to 100 mg/mL of nicotine [18–20]. In our analysis, the nicotine concentration was documented in only 20.5 % of case notes. The reason why the nicotine concentration was not documented in the remaining 79.5 % of case notes is unclear. Potential reasons may include that the nicotine concentration was not listed on the e-liquid bottle, that the caller did not report the nicotine concentration, or that the poison center staff did not record the nicotine concentration reported by the caller. The oral lethal dose of nicotine for adults is estimated to be 50–60 mg, but the source and validity of this estimate are unclear [21]. The lethal dose for children is unknown. A young child who consumes 1–3 mL of e-liquid with a nicotine concentration of 24 mg/mL might be exposed to 24–72 mg of nicotine, potentially exceeding the estimated lethal dose for adults. Most of the health effects commonly reported in the e-cigarette calls were consistent with nicotine exposure [22].

Our analysis has some limitations. First, we likely underestimate the total number of e-cigarette and conventional cigarette exposures leading to adverse health effects because reporting exposures to poison centers is voluntary. The Institute of Medicine estimates that less than half of all poisonings are reported to poison centers, so the number of exposures could be substantially higher [23]. Second, if poison center staffs were unfamiliar with e-cigarettes and their possible acute adverse health effects, then they might have initially

underused the e-cigarette code, might have miscoded e-cigarette calls, or might have been more likely to refer exposed person to health care facilities. Third, this analysis focuses on acute health effects and does not include any potential chronic health effects from nicotine or other chemicals in e-cigarettes. Fourth, poison center staff did not have enough information in almost half of e-cigarette calls and conventional cigarette calls to determine whether a health effect occurred. Therefore, this analysis may have underestimated the true number of calls with an acute adverse health effect. Fifth, because poison centers use a generic e-cigarette code to capture all e-cigarette exposures, we are unable to specify which type of electronic nicotine delivery system (e.g., single-use e-cigarette, vape pen, tank-style device) was involved in the exposure. This limitation is important because the risk for exposure and any resulting health effect might vary based on the device type. Finally, since NPDS data is de-identified, we are not able to determine if some of the patients reported in NPDS were also previously published as case reports.

Based on the increasing use of electronic nicotine delivery systems and the overall increase in poison center calls involving e-cigarettes, it is important for health care providers, the public health community, and the public to be aware of the potential for acute adverse health effects from e-cigarettes. Child-resistant containers and packaging were shown to decrease the mortality rate from unintended ingestions of aspirin and prescription medications in children [24, 25]. Such containers for e-liquid might reduce the number and severity of exposures in children. Messaging advising users of electronic nicotine delivery systems to avoid using the devices around children and to keep the devices and e-liquid out of reach of children also might reduce exposures. A study found that ingestion of conventional cigarettes and cigarette butts by children aged <6 years occurred more frequently in households in which smoking occurred around children and in which conventional cigarettes and cigarette butts were within reach of children [26].

Moreover, clear, standardized labeling of nicotine content and categories might help users choose a product with an appropriate nicotine level and might help health care providers estimate the extent of any nicotine exposure. Such labeling might also reduce the likelihood of unintentional exposure resulting from individuals mistaking e-liquid for other products, such as oral and eye medications. Finally, it is critical for health care providers to also be aware that, although most electronic nicotine delivery systems are designed to deliver nicotine, some devices are designed or can be modified to use other substances, such as marijuana oil [27].

Conclusion

In summary, overall e-cigarette calls to U. S. poison centers increased from 2010 through 2014, and conventional cigarette

calls remained stable. Greater than half of e-cigarette calls involved young children who may be uniquely vulnerable to the acute health effects of nicotine. Compared with conventional cigarette calls, e-cigarette calls to poison centers were more likely to report an adverse health effect and more likely to report a moderate or major health effect. However, the majority of e-cigarette and conventional cigarette calls reporting an adverse health effect were classified as having only a minor effect. Among e-cigarette calls, a wide variety of health effects were reported, including nausea, vomiting, eye pain, conjunctivitis, and headache. Clear labeling of electronic nicotine delivery systems and e-liquid may help prevent inadvertent exposures and may provide data needed to inform health care providers when an exposure occurs. Given the increasing use of electronic nicotine delivery systems and the overall increase in e-cigarette calls, developing strategies to monitor and prevent future poisonings from these novel devices is critical.

Compliance with Ethical Standards

Conflict of Interest None.

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