Electronic Cigarette Exposure: Calls to Wisconsin Poison Control Centers, 2010–2015

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ABSTRACT

Background: E-cigarettes are battery-powered devices that deliver nicotine and flavorings by aerosol and have been marketed in the United States since 2007. Because e-cigarettes have increased in popularity, toxicity potential from device misuse and malfunction also has increased. National data indicate that during 2010–2014, exposure calls to US poison control centers increased only 0.3% for conventional cigarette exposures, whereas calls increased 41.7% for e-cigarette exposures.

Methods: We characterized cigarette and e-cigarette exposure calls to the Wisconsin Poison Center January 1, 2010 through October 10, 2015. We compared cigarette and e-cigarette exposure calls by exposure year, demographic characteristics, caller site, exposure site, exposure route, exposure reason, medical outcome, management site, and level of care at a health care facility.

Results: During January 2010 to October 2015, a total of 98 e-cigarette exposure calls were reported, and annual exposure calls increased approximately 17-fold, from 2 to 35. During the same period, 671 single-exposure cigarette calls with stable annual call volumes were reported. E-cigarette exposure calls were associated with children aged ≤5 years (57/98, 58.2%) and adults aged ≥20 years (30/98, 30.6%). Cigarette exposure calls predominated among children aged ≤5 years (643/671, 95.8%).

Conclusion: The frequency of e-cigarette exposure calls to the Wisconsin Poison Center has increased and is highest among children aged ≤5 years and adults. Strategies are warranted to prevent future poisonings from these devices, including nicotine warning labels and public advisories to keep e-cigarettes away from children.

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INTRODUCTION

E-cigarettes are very popular and widely available members of a larger group of relatively new smoking devices called electronic nicotine delivery systems. In addition to e-cigarettes, these smoking devices include electronic hookahs, hookah pens, vapor pens (pen-like devices similar to e-cigarettes), and vaporizers, as well as electronic cigars and pipes.[1,2] E-cigarettes are metal or plastic tubes that contain a cartridge filled with an e-liquid (EL) solution that is aerosolized by a battery-powered heating element and simulated puffing.[3] ELs typically contain nicotine dissolved in propylene glycol, glycerine, or a mixture of the two,[4] and are available as an individual cartridge or as a refill solution for multiuse cartridges.[2] The aerosol generated from heating ELs can contain harmful substances (eg, diacetyl, formaldehyde, toxic metals, ultrafine particulate matter, and carcinogens).[5,6]

Findings from the 2014 National Youth Tobacco Survey indicated that e-cigarette use (ie, use ≥1/day during the past 30 days) among high school students had increased from 4.5% (approximately 660,000 students) during 2013 to 13.4% (2 million students). Among middle school students e-cigarette use more than tripled, from 1.1% during 2013 to 3.9% during 2014, an increase from approximately 120,000 students to 450,000 students.[7] A consumer-based survey reported a 4-fold increase in the proportion of adults who had tried e-cigarettes between 2009 and 2010.[8] In 2014, the National Health Interview Survey from the National Center for Health Statistics reported that 12.6% of adults had tried e-cigarettes. Furthermore, among cigarette smokers who had tried to quit smoking during the previous year, approximately 50% had tried e-cigarettes and 20.3% were current e-cigarette users.[9]

A particular area of public health concern is how increased availability of e-cigarettes might affect children. These prod-

ucts can be appealing to children because ELs often contain candy-like flavors.[10] Accidental ingestion of nicotine-containing products can cause nicotine poisoning,[8,11] which can result in nausea, vomiting, agitation, confusion, diaphoresis, cardiac arrhythmias, coma, and death.[11] Among children, nicotine toxicity can occur with ingestion of 10–30 mg of nicotine, corresponding to 1 whole conventional cigarette or as little as 1 mL of 36 mg/mL nicotine-containing EL.[8] In January 2016, the Child Nicotine Poisoning Prevention Act was signed into law. This law mandates childproofing of EL containers that contain nicotine.[12] In the absence of this law, childproofing EL products had been voluntary. Product labeling is not covered by this law, and studies have reported that labels are often an inaccurate reflection of EL contents.[13,14]

National studies of poison center data have reported an increasing trend in calls to poison control centers related to e-cigarettes, with a disproportionate percentage of exposures occurring among young children.[8,15] Calls to the poison centers regarding exposures in children are often placed when any exposure or possible exposure to e-cigarettes or cigarettes has occurred, whereas calls to poison centers about adult exposures are placed mainly because of symptoms of poisoning. We examined frequency of calls to the Wisconsin Poison Center during 2010–2015 for e-cigarette exposures and characterize exposures and associated adverse health effects, compared with calls for conventional cigarette exposures.

Figure 1. Number of Calls to the Wisconsin Poison Center for E-cigarette and Cigarette Exposures by Year, January 2010–October 2015

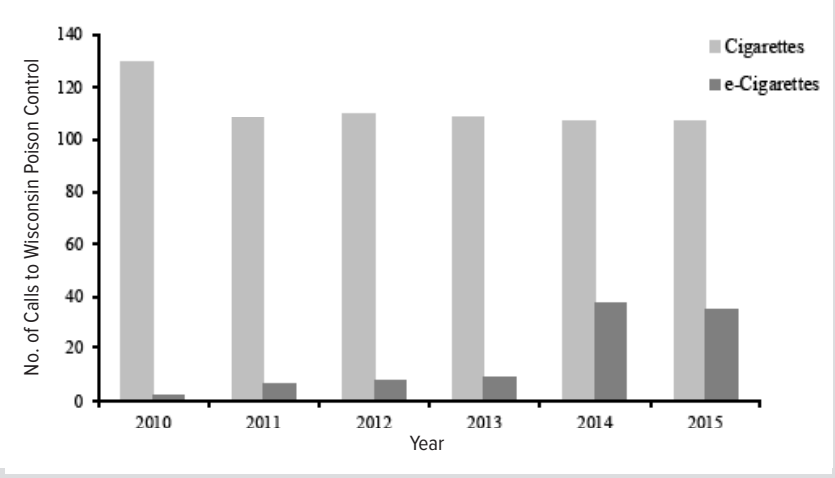
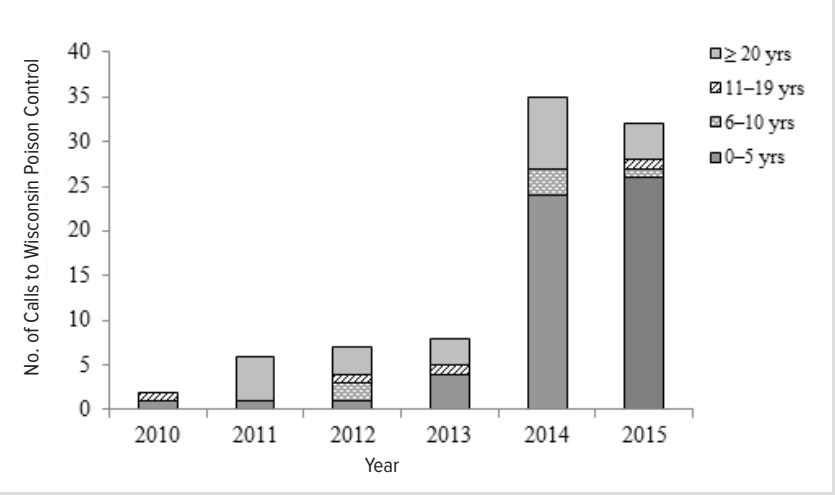


Figure 2. Annual E-cigarette Exposure Calls to the Wisconsin Poison Center by Age Category of the Exposed Person, January 2010–October 2015

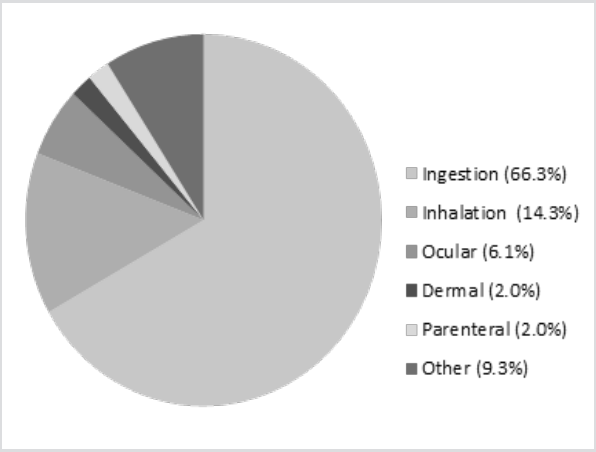


METHODS

We carried out a retrospective review of suspected cigarette and e-cigarette poisonings reported to the Wisconsin Poison Center, a designated regional poison control center located at the Children's Hospital of Wisconsin (Milwaukee, Wisconsin) during January 1, 2010 to October 10, 2015. The Wisconsin Poison Center is staffed 24 hours per day with personnel specifically trained to provide advice regarding suspected poisonings. Personnel perform standardized interviews, electronically record pertinent case information, and upload summary information into the National Poison Data System. The latter served as the primary data source for this study. This data were supplemented with information abstracted from case narratives for all e-cigarette poisoning calls to provide additional details.

An e-cigarette exposure call was defined as a call to the Wisconsin Poison Center for a possible exposure to an e-cigarette, e-cigarette cartridge, or EL. A cigarette exposure call was defined as a call for a possible exposure to tobacco cigarettes or butts. An exposure was defined as any actual or suspected contact with any substance regardless of toxicity or clinical manifestation. Only calls initially classified as exposures by poison center personnel were included in the analysis. Cases initially thought to be exposures were included even if confirmed as nonexposures later (n=4). Calls regarding multiple exposures (eg, cigarettes and ethanol) were excluded from the study,

Figure 3. E-cigarette Exposures by Route (N=98)



because they were limited (n=7), and our focus was exclusively e-cigarette poisonings.

Cigarette and e-cigarette exposure groups were compared by year of exposure, demographic characteristics, caller site, exposure site, exposure route, exposure reason, medical outcome, management site, and level of care at a health care facility. These categories (Table 1) follow the National Poison Data System coding scheme developed by the American Association of Poison Control Centers.[16]

RESULTS

The Wisconsin Poison Center received 98 e-cigarette and 671 cigarette exposure calls January 1, 2010 through October 10, 2015. Annual number of calls for e-cigarette exposures increased from 2 during 2010 to 35 during 2015 (as of October), a >17-fold increase (Figure 1). When reviewing e-cigarette and conventional cigarette exposures combined, e-cigarette exposures accounted for 1.5% of calls during 2010, compared with 25.7% of calls during 2014, also an approximately 17-fold increase. The annual number of calls for cigarette exposures remained stable during this period (Figures 1, 2).

As displayed in Figure 2, e-cigarette exposures occurred primarily among individuals ≤5 and ≥20 years of age. The proportion of e-cigarette exposures among children ≤5 years of age, compared with other age groups, increased during the study period (Figure 2). During the same timeframe, cigarette exposures occurred primarily among children ≤5 years of age. E-cigarette exposures occurred mostly among males, while conventional cigarette exposures were distributed approximately evenly between males and females. Similar trends by sex were observed among children ≤5 years of age, for both e-cigarette and cigarette exposure. Most e-cigarette and cigarette exposures occurred at the patient's home, therefore it is not surprising that most exposure calls for both study groups originated from the exposed person's residence. Predominant exposure routes for e-cigarettes were ingestion, followed by inhalation, ocular, and dermal, as well as parenteral exposures (Figure 3). Combined exposures (eg, ingestion and dermal) were few and categorized as "Other." For conventional cigarettes, ingestion and inhalation were the only exposure routes.

In our analysis, the majority of exposures among patients ≤5 years of age were from the ingestion of EL during an unsupervised period. Exposures among patients ≥20 years of age were mainly unintentional because of malfunction of the e-cigarette resulting in ingestion of EL while attempting to smoke. Ocular exposures also occurred in this age category, because of some patients mistakenly using the EL container as eye drops or accidentally spraying EL in the eye while attempting to refill an e-cigarette. Intentional misuse such as deliberate ingestion or intravenous injection of EL also happened in a small number of e-cigarette exposures (Table).

Case report reviews revealed that for a number of e-cigarette exposure calls, the Wisconsin Poison Center personnel were uncertain of the level of exposure and had to look to external sources (eg, the websites of EL manufacturers) to get information about what chemicals and dose to which persons might have been exposed.

With regard to medical outcome, a majority of individuals with exposures to e-cigarettes and cigarettes were asymptomatic or had symptoms of limited severity. Minor, rapidly resolving symptoms frequently involving mucous membranes were observed in approximately one-third of e-cigarette and cigarette exposures. Moderate effects, defined as patients having more prolonged or systemic symptoms that required treatment, occurred among 4.1% e-cigarette and <1.0% cigarette exposures. For approximately one-fourth of e-cigarette and cigarette exposures, the medical outcomes were not known or were determined to be unrelated to the exposure.

Among e-cigarette and cigarette exposures that resulted in either minor or moderate effects, emesis was the predominant adverse effect, mainly because of ingestion of EL or cigarettes or cigarette butts. Coughing and choking was also a notable adverse effect of cigarette exposures, but this was not an observed consequence of e-cigarette exposures. One patient in our study had an acute allergic reaction after using a cinnamon flavored e-cigarette. The manufacturer eventually stopped production of this EL because of potential adverse health effects from the cinnamon flavoring.[17]

Moderate effects resulting from e-cigarette exposures occurred among 3 adults and 1 child. One patient fell asleep and EL containing 100 mg of nicotine spilled on his abdomen and arm. This patient experienced nausea, vomiting, headache, and abdominal pain and was treated at an emergency department and released after symptoms ceased. Another exposure resulting in a moderate effect occurred when a person possibly injected EL intravenously with a 100 mL syringe. The emergency department provided supportive care for diaphoresis and pallor. He was later admitted to the psychology department. A moderate effect also occurred in an

asthmatic child age 6 years who took a puff from an e-cigarette resulting in bronchospasm and coughing. The child's symptoms were managed at home with a nebulizer. Finally, an adult experienced chest pain after inhaling EL when his e-cigarette malfunctioned. The patient was evaluated at an emergency department, released, and lost to follow-up.

Most patients were safely managed at home after exposures to either e-cigarettes or cigarettes. At the time of call to the Wisconsin Poison Center, some patients were already en route to a health care facility. Poison center personnel referred a small number of patients to a health care center. Most patients who were referred to, or were already en route to a health care facility at the time of call were exposed to e-cigarettes (Table).

DISCUSSION

E-cigarettes have been marketed in the United States since 2007. Between 2010 and October 2015, there was an approximate 17-fold increase in annual e-cigarette exposure calls to the Wisconsin Poison Center. The trend is similar to that seen in recent national data. The increase in annual e-cigarette exposure calls coincides with an increase of e-cigarette use, especially between 2013 and 2014.[7]

Our study reported that the highest percentage of calls for e-cigarette exposures were for children ≤5 years of age, followed by adults ≥20 years of age. This trend is similar to national studies, which reported e-cigarette exposures were more frequent among children ≤5 years of age,[8,18-20] followed by adults between age 20–39 years.[8] The majority of exposures among these age groups resulted in none or minor effects. This finding is supported by a study concerning e-cigarette exposure calls to Texas poison centers, which also reported that the majority of exposures resulted in minor effects.[19] Interestingly, exposures to e-cigarettes occurred predominantly among males in this analysis, a finding that was not observed in similar studies.[18-19] Most exposures among children ≤5 years of age occurred at and were well managed at home. Our results are consistent with a study in which approximately 80% of e-cigarette exposures occurred at the residence of the exposed person.[8] This result is expected, because 1 study reported that most daily e-cigarette users smoke at home and refill their e-cigarette ≥5 times per day.[21]

The site of exposure management varied between the 2 study groups. Compared with cigarette exposure calls, a larger proportion of calls regarding e-cigarette exposures were placed while en route to a health care facility. We hypothesize that because of ambiguous labeling and novelty of e-cigarettes and ELs, the exposure was perceived as a substantial threat to the exposed individual's health that warranted visiting a health care facility versus calling the poison center.

Our study reported that toxicity assessment and responses by Wisconsin Poison Center personnel were complicated by incon-

Table. Wisconsin Poison Center (WPC) Calls by Caller Site, Exposure Site, Exposure Route, Reason for Exposure, Medical Outcome, Management Site, and Level of Care at a Health Care Facility, January 2010–October 2015

	E-cigarette Total N=98	%	Cigarette Total N=671	%
Caller Site				
Own residence	70	71.4	550	82.0
Health care facility (HCF)	18	18.4	45	6.7
Other	7	7.1	50	7.5
Workplace	3	3.1	6	0.9
Other residence	—	—	18	2.7
School	—	—	1	0.1
Public area	—	—	1	0.1
Exposure Site				
Own residence	89	90.8	612	91.2
Other residence	4	4.1	39	5.8
Workplace	2	2	—	—
Health care facility (HCF)	1	1	—	—
School	1	1	1	0.1
Public area	1	1	9	1.3
Other	—	—	7	1
Unknown	—	—	3	0.7
Exposure Route				
Ingestion	65	66.3	667	99.4
Inhalation and nasal	14	14.3	4	0.6
Ocular	6	6.1	—	—
Ingestion and dermal	5	5.1	—	—
Dermal	2	2	—	—
Ingestion, inhalation and nasal	2	2	—	—
Parenteral	2	2	—	—
Ingestion and ocular	1	1	—	—
Inhalation, nasal and dermal	1	1	—	—
Exposure Reason				
Unintentional — general	71	72.4	658	98.1
Unintentional — misuse	11	11.2	3	0.4
Unintentional — therapeutic error	3	3.1	—	—
Intentional — misuse	5	5.1	2	
Intentional — abuse	2	2	1	0.1
Intentional — suspected suicide	1	1	—	—
Intentional — unknown	—	—	3	0.4
Adverse reaction — other	4	4.1	1	0.1
Other — contamination or tampering	1	1	3	0.4
Medical Outcome				
No effect	37	37.8	312	46.5
Minor effect	37	37.8	178	26.5
Moderate effect	4	4.1	5	0.7
Not followed, minimal clinical effects possible	13	13.3	126	18.8
Not followed, judged as nontoxic exposure	2	2.0	21	3.1
Unable to follow, judged as a potentially toxic exposure	3	3.1	11	1.6
Unrelated effect, exposure was probably not responsible for effect	2	2.0	14	2.1
Confirmed nonexposure	—	—	4	0.6
Management Site				
Patient was managed on site (non-HCF)	62	63.3	603	89.9
Patient en route to/in HCF when WPC called	21	21.4	43	6.4
Patient was referred by WPC to a HCF	15	15.3	22	3.3
Other	—	—	1	0.1
Unknown	—	—	2	0.3
Level of Health Care Facility Care				
Evaluated, treated and released	20	20.4	55	8.2
Patient lost to follow-up or left against medical advice	7	7.1	9	1.3
Patient refused referral or did not arrive at HCF	5	5.1	—	—
Admitted to non-critical care unit	1	1.0	1	0.1
Unknown	65	66.3	606	90.3

sistent and misleading labeling of EL containers. In multiple e-cigarette cases, personnel had difficulty identifying the actual nicotine dose ingested to determine whether it might have been toxic to the person. Labels on numerous EL containers do not state concentration, nor specify whether the amount of nicotine listed on the label refers to the concentration or total amount of nicotine in the EL container. In certain cases, poison center personnel had to refer to the EL manufacturer's website to determine nicotine concentration. This was complicated by the fact that the concentration of nicotine listed on the labels of EL containers can be markedly different from measured values.[5]

This study has certain limitations. The Wisconsin Poison Center is dependent on self-reported exposures. Potential for case ascertainment bias exists, because exposures among children generally are more likely to be reported than those among adults. This is because, essentially, concerns about potential poisonings in children are more worrisome than concerns about potential poisonings in adults. As mentioned in a previous study,[8] variations among poison center personnel in categorizing cases has been noted, leading to miscoding of exposure characteristics. Furthermore, not all exposures to e-cigarette and cigarettes may have been reported to the Wisconsin Poison Center. Lastly, a small number of calls regarding an exposure to e-cigarettes or cigarettes paired with another type of exposure were excluded from this analysis. Because of these factors, the e-cigarette exposures reported here are likely an underestimate of all exposures among the general population.[8]

CONCLUSIONS

The increase in unintended child exposures to e-cigarettes warrants robust public health surveillance of e-cigarette use and adverse events. Future studies will determine if child proofing substantially reduces the number of child poisoning incidents. Incomplete or inaccurate labeling delays emergency department or poison control personnel from implementing correct and potentially lifesaving treatments.

Reminding the public to keep ELs and e-cigarettes away from children is critical. Furthermore, implementation of national strategies to prevent future exposures, such as consistent product content labeling, is urgently needed.

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