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Research

Electronic cigarette exposures reported to the British Columbia Drug and Poison Information Centre: an observational case series

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Abstract

Background: Electronic nicotine delivery systems (ENDSs), including electronic cigarettes (e-cigarettes), are rapidly gaining popularity. The aim of this study was to use poison centre data to describe epidemiological trends in ENDS-related exposures.

Methods: We conducted an observational case series study using records containing both coded fields and free-text narratives from the British Columbia Drug and Poison Information Centre for all calls involving exposure to ENDS received from 2012 to 2017. We described trends in exposures and exposed people, as well as clinical effects.

Results: A total of 243 calls were recorded for 186 unique exposures to ENDS devices, e-juice, e-cigarette cartridges and other associated paraphernalia over the study period. Calls related to ENDS exposures increased nearly sixfold between 2013 and 2014 and did not decline subsequently. Exposures were most frequently documented in children aged 4 years or less (81 [43.5%]), with 58 (31.0%) in 1- and 2-year-olds. Seventy-two exposures (89%) in children aged 4 years or less were due to accidental ingestion, whereas adults aged 25 years or more called the poison centre following ENDS malfunctions (7 [23%], spills (4 [13%]) and exposure to e-juice mistaken for other substances (4 [13%]). Of the 186 exposed people, 87 (46.8%) reported symptoms.

Interpretation: British Columbia experienced a sixfold increase in ENDS-related calls to the provincial poison centre between 2012 and 2017, driven by ingestions in young children. Regulatory approaches aimed at minimizing children's access to ENDS, clear labelling of nicotine concentration, and packaging that reduces the likelihood of spills, product confusion and malfunction should be considered.

Electronic nicotine delivery systems (ENDSs), including electronic cigarettes (e-cigarettes), were first introduced to North American markets in 2007. They are designed to vaporize inhalable chemical combinations for an experience that mimics smoking.[1] Devices typically include an electronic heating and aerosolization system and a cartridge of "e-juice" or "e-liquid," a variable mixture of propylene glycol (a carrier compound), glycerol, nicotine and flavouring.[2] Although the overall prevalence of traditional cigarette smoking has been declining, ENDS use is increasing, particularly among middle and high school students, the first increase in nicotine product use in decades.[3–8]

In the United States, the National Poison Data System uses near–real-time data from 55 poison control centres for monitoring and surveillance. Poison centres in that country have reported increases in the frequency of ENDS-related calls.[9–12] Although most calls involve minimal toxic effects,[11,13] case reports have documented severe neurologic symptoms, anoxic brain injury and death resulting from unintentional pediatric ingestion of e-juice.[14,15] The primary known hazard associated with ENDS exposure is nicotine, which is absorbed through the skin, alveoli and oropharyngeal/gastrointestinal mucosa.[14] Although nicotine is most commonly associated with central nervous system excitation, excessive or prolonged exposure can result in loss of receptor specificity and paradoxical inhibition, causing cholinergic toxicity and blockade at the neuromuscular junction. The lethal adult dosage of nicotine is estimated at less than 1 mg/kg.[14] Many ENDSs (including "nicotine-free" formulations) contain nicotine in excess of their labelled concentrations.[16–19] We examined all ENDS-related calls to British Columbia's poison centre, exploring trends in exposures, those exposed, causes of exposures and clinical outcomes within a rapidly changing use environment and the Canadian context.

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Methods

Data sources

The British Columbia Drug and Poison Information Centre (DPIC) provides toll-free poison information and treatment recommendations to the general public and health care professionals of British Columbia (population 4.8 million) 24 hours a day, 7 days a week.[20,21] The DPIC pharmacists and nurses, who are trained on site, certified by the American Association of Poison Control Centers and supported by medical toxicologists, consult on over 26 000 calls each year.[22] The public can call the DPIC directly or be transferred to the DPIC should they call HealthLink BC about exposure to a potentially dangerous substance or medication. Group homes, emergency medical technicians and clinicians call the DPIC for assistance in managing poisonings. In cases in which the exposed person can be managed at home, the DPIC requests or initiates follow-up until the person's condition is stable and, if the person is advised to seek further treatment, collects information on clinical outcome.

Product information is entered with the use of American Association of Poison Control Centers generic codes and product codes, and Poisindex (IBM Corporation) descriptors. All data are maintained in an electronic database. We reviewed all e-cigarette and ENDS-related calls received between Jan. 1, 2012, and Dec. 31, 2017 coded as American Association of Poison Control Centers 200620: electronic cigarettes: device containing nicotine without added flavours; 200622: electronic cigarettes: nicotine device with added flavours; 310095: electronic cigarettes: nicotine liquid flavor unknown; or 310094: electronic cigarettes: nicotine device flavour unknown.

Design

We captured all exposure-related calls, regardless of toxic effects, clinical symptoms or outcomes. Some exposures led to multiple calls, and some callbacks were initiated by the DPIC. To avoid double counting, we counted multiple calls regarding a single exposure once, although information was extracted from the entire longitudinal call record. Exposures involving multiple coingested substances were included in all analyses except those describing symptoms and care trajectory, since ENDS-attributable symptoms could not be reliably disaggregated. Nonhuman exposures and callers purely seeking information were excluded.

We obtained the call records containing coded fields and free-text narratives for all ENDS-related calls. Two coauthors (A.C. and M.L.) reviewed the free-text narratives and verified all coded fields (Appendix 1, available at www.cmajopen.ca/content/7/3/E462/suppl/DC1). Coded fields that were assessed included the age and gender of the exposed person, relationship to the caller, route of exposure, location of exposure, coingested substances and timing of both the call and the exposure.

We abstracted additional data from the free-text narrative into predetermined standardized fields. We reviewed the free-text narrative to assess the vehicle of exposure (e.g., ENDS device, e-cigarette cartridge, e-juice or e-liquid), source (self, household member, other person, workplace, found object), cause (e.g., accidental access, device malfunction, usual use, misuse) and clinical symptoms. In cases in which the flavour, nicotine content, nicotine concentration and/or dosage appeared in the coded fields or the free-text narrative, it was recorded.

In keeping with the biphasic pattern typical of toxic nicotine effects, we classified symptoms as stimulatory or depressive. Calls in which nausea, vomiting, headache, dizziness, anxiety and/or tachycardia were noted were coded as "stimulatory effects typical of low-level nicotine exposure,"[23–25] and calls in which seizure, coma and/or respiratory failure were reported were coded as "depressive effects typical of high-level nicotine exposure."[23,26,27] If both stimulatory and depressive effects were reported, both were recorded. In cases in which only symptoms other than those listed above were noted, we applied the code "not typical of exposure to nicotine."

We extracted the number of patient callbacks and the interval between the recorded time of exposure and the last contact with the DPIC from the free-text record. The clinical trajectory (managed at the caller's site, assessed at a health care facility or admitted) was abstracted from the standardized fields.

To assess whether calls were received in proportion to where BC residents live, we allocated callers to BC's 16 Health Service Delivery Areas.[28] We also categorized the exposed person's place of residence (which is routinely recorded) as metropolitan, mixed urban/rural or remote using the BC Ministry of Health's geographic service area definitions.[29]

Statistical analysis

We described characteristics of ENDS exposures and exposed people using frequencies and proportions. These were stratified by age, route of exposure and nicotine concentration. We compared age, gender and geographic area to those of the BC population using the χ^2 test. We assessed trends for the presence or absence of symptoms and care trajectory as a function of nicotine concentration at exposure using the Cochran–Armitage test.

Ethics approval

We consulted the BC Centre for Disease Control privacy officer, who advised that ethics approval was not required given that the data were depersonalized, nonidentifiable and used solely for the purposes of surveillance and quality assurance.

Results

Characteristics of exposures and exposed people

From 2012 to 2017, 243 calls were recorded for 186 unique exposures to ENDS devices, e-juice, e-cigarette cartridges and other associated paraphernalia, for a rate of 0.02 unique exposures/year per 100 000 population. Calls regarding ENDS exposure were infrequent in 2012 and 2013; a nearly sixfold increase occurred in 2014, and the number of calls did not abate in subsequent years (Table 1). From 2014 to 2017, there was a mean of 43 (range 39–47) calls per year.

Of the 186 exposures, 108 (58.1%) concerned males, and the median age was 3 years (range 1–75 yr). Exposures were

most frequently reported in 1-year-olds (30 [16.1%]), followed by 2-year-olds (28 [15.1%]) and infants less than 1 year (11 [5.9%]). A small second peak was seen in adolescents aged 15–16 years (11 [5.9%]) (Figure 1). The increase in calls over the study period was driven by exposures in young children (Figure 2).

Most exposures (175 [94.1%]) occurred at the exposed person's place of residence, 6 (3.2%) occurred in a public area, 2 (1.1%) occurred at workplaces, and 1 (0.5%) occurred in a school; the location was unknown for the remaining 2 exposures. Of the 72 exposed children aged 4 years or less for whom location was known, 68 (94%) accessed an ENDS or ENDS paraphernalia in their own households.

People from rural and remote areas accounted for 41 (22.0%) of the exposures but only 11.9% of the province's population. Three of the top 5 highest rates of regional

Table 1: Characteristics of calls to the British Columbia Drug and Poison Information Centre concerning exposure to electronic nicotine delivery systems and demographic characteristics of exposed people, 2012–2017

Characteristic	No. (%) of people: Exposures reported to BC poison centre *n* = 186	No. (%) of people: BC population[20,21] *n* = 4 648 060	χ^2	Degrees of freedom	*p* value
Demographic characteristics of exposed people					
Gender			6.9	1	0.009
Female	76 (40.9)	2 370 000 (51.0)			
Male	108 (58.1)	2 279 000 (49.0)			
Unknown*	2 (1.1)	–			
Age, yr			874.0	4	< 0.001
≤ 4	81 (43.5)	221 000 (4.8)			
5–14	7 (3.8)	471 000 (10.1)			
15–19	18 (9.7)	259 000 (5.6)			
20–24	7 (3.8)	288 000 (6.2)			
≥ 25	31 (16.7)	3 410 000 (73.4)			
Not recorded*	42 (22.6)	–			
Temporal and geographic characteristics of calls					
Year		–			
2012	7 (3.8)				
2013	7 (3.8)				
2014	39 (21.0)				
2015	47 (25.3)				
2016	40 (21.5)				
2017	46 (24.7)				
Time of day		–			
0600–1159	31 (16.7)				
1200–1759	71 (38.2)				
1800–2359	72 (38.7)				
0000–0559	12 (6.4)				
Geographic area			30.6	2	< 0.001
Metropolitan	77 (41.4)	2 643 866 (56.4)†			
Mixed urban/rural	62 (33.3)	1 485 317 (31.7)†			
Rural/remote	41 (22.0)	561 395 (12.0)†			
Not recorded*	6 (3.2)	–			

*Those with missing data were not included in comparisons.
†Source: B.C. Health System Strategy Geographic Service Areas.[29]

ENDS exposure were geographically clustered in Vancouver Island's 3 Health Service Delivery Areas, 1 of which had the highest rate of reported exposures in the province (8.5/100 000 residents).

Exposures and clinical sequelae

Exposure characteristics by age are presented in Table 2. Exposures in children less than age 5 years were almost always the result of accidental access to (77 [95%]) and ingestion of

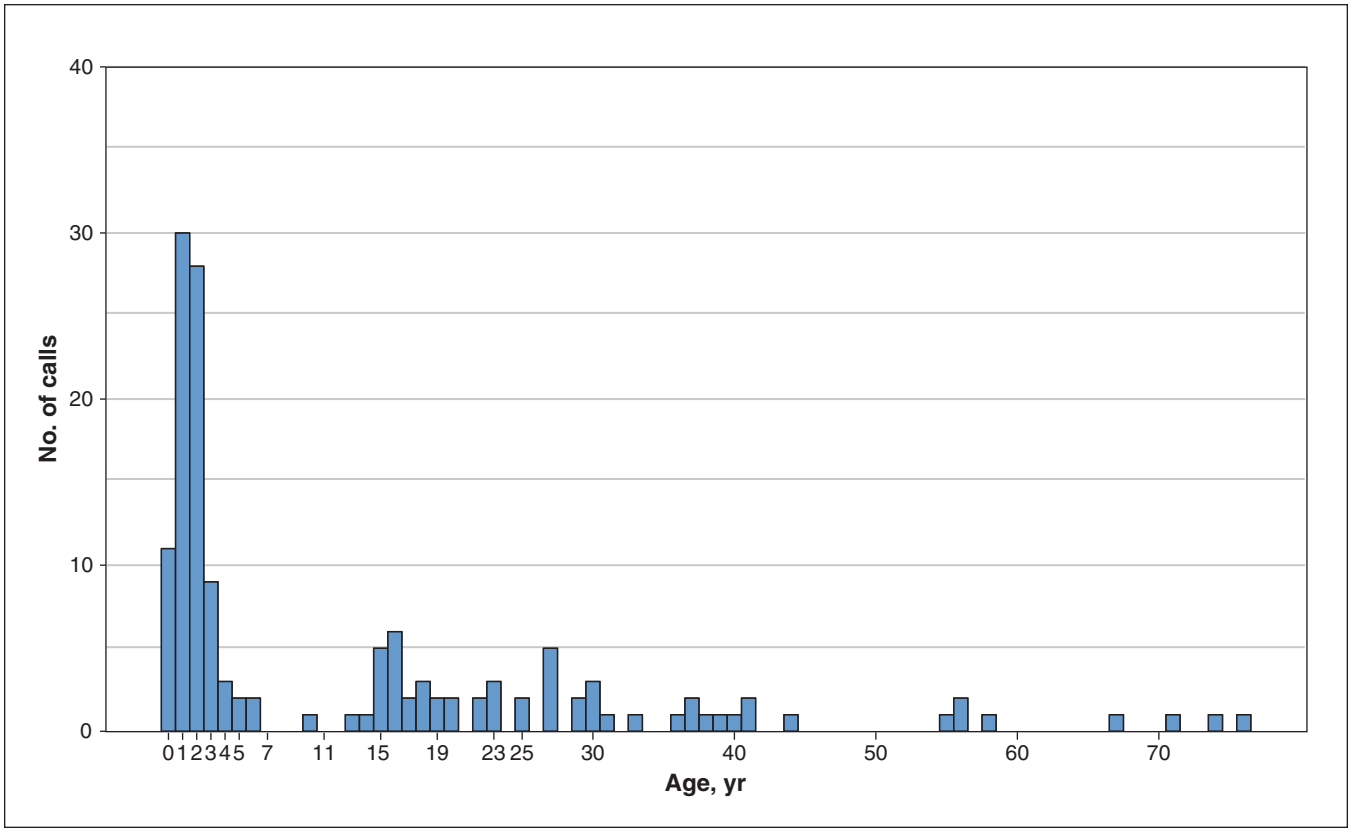

Figure 1: Frequency of unique exposure calls to the British Columbia Drug and Poison Information Centre for exposure to electronic nicotine delivery systems by age, 2012–2017.

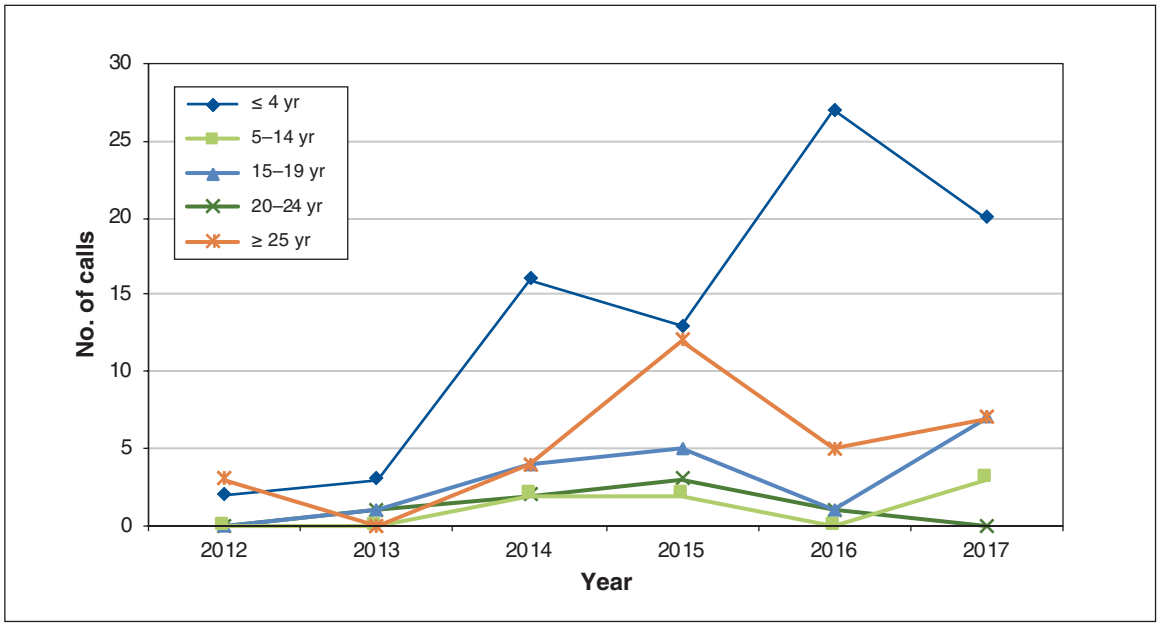

Figure 2: Frequency of unique exposure calls to the British Columbia Drug and Poison Information Centre for exposure to electronic nicotine delivery systems by age group and year.

(43 [53%]) bottled e-juice. Adults aged 25 years or more called the poison centre following spills in 4 cases (13%), ENDS malfunction in 7 (23%) and mistaking e-juices for other substances such as eyedrops in 4 (13%). Four exposures were coded as chronic, defined as "continuous, repeated, or intermittent" and lasting more than 8 hours.[30]

Table 2: Characteristics of exposures to electronic nicotine delivery systems, symptoms and care trajectories, by age group

Characteristic	Age group, yr; no. (%) of people						
	≤ 4 *n* = 81	5–14 *n* = 7	15–19 *n* = 18	20–24 *n* = 7	≥ 25 *n* = 31	Unknown *n* = 42	Total *n* = 186
Cause of exposure							
Accidental access*	77 (95)	4 (57)	2 (11)	0 (0)	0 (0)	2 (5)	85 (45.7)
Handling device†	0 (0)	1 (14)	3 (17)	1 (14)	1 (3)	4 (10)	10 (5.4)
Intentional inappropriate use	0 (0)	1 (14)	1 (6)	1 (14)	2 (6)	2 (5)	7 (3.8)
Making e-juice	0 (0)	0 (0)	0 (0)	0 (0)	1 (3)	0 (0)	1 (0.5)
E-cigarette malfunction	1 (1)	0 (0)	2 (11)	0 (0)	7 (23)	7 (17)	17 (9.1)
Mistaken identity‡	1 (1)	0 (0)	0 (0)	1 (14)	4 (13)	6 (14)	12 (6.4)
Spill	1 (1)	0 (0)	1 (6)	2 (29)	4 (13)	5 (12)	13 (7.0)
Usual e-cigarette use	0 (0)	0 (0)	7 (39)	1 (14)	10 (32)	7 (17)	25 (13.4)
Other/not recorded	1 (1)	1 (14)	2 (11)	1 (14)	2 (6)	9 (21)	16 (8.6)
Vehicle of exposure							
E-cigarette device	19 (23)	0 (0)	12 (67)	3 (43)	19 (61)	21 (50)	74 (39.8)
E-cigarette cartridge	11 (14)	1 (14)	1 (6)	1 (14)	1 (3)	2 (5)	17 (9.1)
Bottled e-juice	50 (62)	6 (86)	5 (28)	3 (43)	11 (35)	18 (43)	93 (50.0)
Other/not recorded	1 (1)	0 (0)	0 (0)	0 (0)	0 (0)	1 (2)	2 (1.1)
Route of exposure§							
Dermal	6 (7)	1 (14)	2 (11)	2 (29)	4 (13)	7 (17)	22 (11.8)
Ingestion	72 (89)	6 (86)	8 (44)	4 (57)	14 (45)	18 (43)	122 (65.6)
Inhalation	2 (2)	0 (0)	8 (44)	1 (14)	10 (32)	7 (17)	28 (15.0)
Nasal	0 (0)	0 (0)	0 (0)	0 (0)	1 (3)	0 (0)	1 (0.5)
Ocular	1 (1)	0 (0)	0 (0)	0 (0)	2 (6)	9 (21)	12 (6.4)
Vaginal	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (2)	1 (0.5)
Symptoms present¶							
Yes	9 (11)	3 (43)	16 (89)	4 (57)	27 (87)	28 (67)	87 (46.8)
No	54 (67)	4 (57)	1 (6)	2 (29)	2 (6)	7 (17)	70 (37.6)
Not recorded	18 (22)	0 (0)	1 (6)	1 (14)	2 (6)	7 (17)	29 (15.6)
Care trajectory							
Managed outside of health care facility**	50 (62)	6 (86)	12 (67)	6 (86)	24 (77)	33 (79)	131 (70.4)
Treated/evaluated at health care facility and released	22 (27)	0 (0)	2 (11)	0 (0)	5 (16)	3 (7)	32 (17.2)
Admitted to noncritical care unit	2 (2)	1 (14)	2 (11)	1 (14)	1 (3)	1 (2)	8 (4.3)
Admitted to critical care unit	1 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (0.5)
Lost to follow-up	6 (7)	0 (0)	2 (11)	0 (0)	1 (3)	5 (12)	14 (7.5)

Note: e-cigarette = electronic cigarette.
*Accidental acquisition of electronic nicotine delivery system or associated paraphernalia by a person (usually a child) who is not the intended user and subsequent use without the intention of causing harm.
†Includes cleaning, refilling or otherwise manipulating electronic nicotine delivery system and cartridges.
‡E-juice mistaken for another substance (e.g., eyedrops), frequently housed in a similar container.
§Cases with multiple routes of exposure were counted in all applicable categories.
¶Excludes coingestions as these substances may have contributed to symptomatology.
**Includes during emergency transportation.

Nine people identified a second exposure that may have contributed to the clinical picture. Of the 9, 2 were exposed to a second nicotine-containing substance, 2 had recently undergone a change in psychotropic medications, 1 was exposed to alcohol (and potentially γ-hydroxybutyric acid), 1 was exposed to tetrahydrocannabinol, 1 was exposed to gun oil, and 1 was exposed to analgesics, possibly including opioids; the remaining person was exposed to acetaminophen and acetaminophen plus codeine. There were no calls about second-hand exposure to ENDS vapours.

Nearly half (87 [46.8%]) of those exposed reported symptoms. Although only 9 children (11%) aged 4 years or less were documented to be symptomatic, 25 (31%) were seen at health care facilities. In contrast, 16 (89%) of those aged 15–19 were symptomatic, but only 4 (22%) were seen at health care facilities (Table 2).

Ninety-seven callers (52.2%) provided the labelled concentration of their ENDS products. Three (75%) of the 4 exposed to "no-nicotine" solutions experienced symptoms, compared to 7 (39%) of those exposed to low-level nicotine solutions, 15 (28%) of those exposed to medium-level solutions, 6 (40%) of those exposed to high-level solutions and 4 (57%) of those exposed to solutions with very high nicotine levels (Table 3). Of the 87 cases in which symptoms were noted, 42 (48%) were typical of low-level systemic nicotine exposure. Only 2 exposures (2%), both ingestions, were associated with systemic symptoms compatible with high-level nicotine dosing (Table 4). The symptoms and care trajectories for the 49 exposures in children aged 4 years or less for which the nicotine concentration was available or could be estimated are presented in Table 5.

Excluding chronic exposures, the median time between the exposure and the initial call to the poison centre was 10 minutes (range 0 min to 62 d). Ninety-five callers (51.1%) telephoned the poison centre within 10 minutes, and 153 (82.2%) within 60 minutes. The number of callbacks and the duration of contact with the poison centre were highest for those exposed to e-juice containing higher concentrations of nicotine (Table 6).

Missing information and absent fields

The volume of exposure was not specified in 130 call records (70.4%). Product names and characteristics were recorded in less than 5 cases. A total of 119 call records (64.0%) contained no mention of flavouring. Packaging attributes (e.g., child-proof packaging) were not recorded.

Interpretation

The BC DPIC experienced an increase in calls regarding ENDS exposures between 2012 and 2017, predominantly

Table 3: Age of exposed person, presence of symptoms and care trajectory, by nicotine concentration of electronic nicotine delivery system product*

Variable	Nicotine concentration, mg/mL; no. (%) of people				
	0 *n* = 4	0.1–5 *n* = 18	6–17 *n* = 53	18–23 *n* = 15	≥ 24 *n* = 7
Age group, yr					
≤ 4	0 (0)	8 (44)	33 (62)	9 (60)	4 (57)
5–14	0 (0)	4 (22)	0 (0)	0 (0)	0 (0)
15–19	1 (25)	1 (6)	6 (11)	0 (0)	1 (14)
20–24	0 (0)	1 (6)	2 (4)	1 (7)	0 (0)
≥ 25	1 (25)	2 (11)	7 (13)	3 (20)	1 (14)
Not recorded	2 (50)	2 (11)	5 (9)	2 (13)	1 (14)
Symptoms present					
Yes	3 (75)	7 (39)	15 (28)	6 (40)	4 (57)
No	0 (0)	11 (61)	29 (55)	7 (47)	1 (14)
Not recorded	1 (25)	0 (0)	9 (17)	2 (13)	2 (29)
Care trajectory					
Managed outside of health care facility†	3 (75)	13 (72)	37 (70)	11 (73)	5 (71)
Treated/evaluated at health care facility and released	1 (25)	4 (22)	10 (19)	3 (20)	2 (29)
Admitted to noncritical care unit	0 (0)	0 (0)	2 (4)	1 (7)	0 (0)
Lost to follow-up	0 (0)	1 (6	4 (8)	0 (0)	0 (0)

*Excludes cases in which nicotine concentration was not recorded.
†Includes during emergency transport.

Table 4: Symptoms by route of exposure*

Variable	Route; no. (%) of people			
	Dermal† *n* = 22	Ingestion† *n* = 122	Inhalation† *n* = 28	Total‡ *n* = 186
Symptoms present				
Yes	12 (54.5)	38 (31.1)	25 (89.3)	87 (46.8)
No	7 (31.8)	60 (49.2)	2 (7.1)	70 (37.6)
Not recorded	3 (13.6)	24 (19.7)	1 (3.6)	29 (15.6)
Symptoms§				
Local				
Dermal	4 (18.2)	0 (0.0)	1 (3.6)	5 (2.7)
Oral/pharyngeal	0 (0.0)	7 (5.7)	1 (3.6)	9 (4.8)
Respiratory	0 (0.0)	1 (0.8)	1 (3.6)	3 (1.6)
Ocular	0 (0.0)	0 (0.0)	0 (0.0)	11 (5.9)
Vaginal	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.5)
Systemic				
Not typical for nicotine exposure	4 (18.2)	19 (15.6)	11 (39.3)	45 (24.2)
Typical for low nicotine exposure	8 (36.4)	18 (14.8)	15 (53.6)	42 (22.6)
Typical for high nicotine exposure	0 (0.0)	2 (1.6)	0 (0.0)	2 (1.1)

*Excludes people with coingestions as these substances may have contributed to symptomatology.
†Excludes people with multiple routes of exposure.
‡Includes people with nasal, ocular and vaginal exposures as well as multiple routes of exposure.
§Some people experienced multiple symptoms.

Table 5: Symptoms and care trajectories for the 49 exposures in children aged 4 years or less for which the nicotine concentration was available or could be estimated, by nicotine concentration of the product ingested

Variable	Nicotine concentration, mg/mL; no. (%) of children*			
	0.1–5 *n* = 7	6–17 *n* = 30	18–23 *n* = 11	≥ 24 *n* = 1
Symptoms†				
Present	0 (0)	1 (3)	3 (27)	0 (0)
Absent	7 (100)	22 (73)	5 (45)	0 (0)
Not recorded	0 (0)	7 (23)	3 (27)	1 (100)
Care trajectory‡				
Managed outside health care facility	3 (43)	19 (63)	7 (64)	1 (100)
Seen at health care facility	3 (43)	8 (27)	3 (27)	0 (0)
Admitted	0 (0)	0 (0)	1 (9)	0 (0)
Lost to follow-up	1 (14)	3 (10)	0 (0)	0 (0)

*Three children who ingested electronic cigarette products were admitted to hospital, but no product nicotine concentration was recorded.
†Cochran–Armitage test for trend = 7.73, 2 degrees of freedom, $p = 0.02$.
‡Cochran–Armitage test for trend = 5.36, 6 degrees of freedom, $p = 0.5$.

Table 6: Callbacks and duration of contact with BC poison centre for children aged 4 years or less, by nicotine concentration of the electronic nicotine delivery system product ingested*

Variable	Nicotine concentration, mg/mL; no. (%) of children			
	0.1–5 *n* = 7	6–17 *n* = 30	18–23 *n* = 11	≥ 24 *n* = 1
No. of callbacks				
0	5	11	2	0
1	1	9	5	1
2	1	7	2	0
3	0	1	1	0
4	0	1	0	0
5	0	1	0	0
6	0	0	1	0
Interval between time of exposure and time of last call, min	–	–	–	78
Percentile				
25th	30.0	21.0	62.3	
50th	45.0	77.2	108.7	
75th	93.0	127.2	196.5	
95th	216.6	265.9	1244.3	

*Cases in which the concentration of the electronic nicotine delivery system product was known.

regarding young children who accessed ENDS paraphernalia accidentally. There was a weak indication that adolescents might have been the subject of calls more frequently than older children or adults. Apart from usual e-cigarette use, adults most frequently called regarding spills and device malfunctions. Nearly half of those exposed were asymptomatic, and only 8 (4.3%) required assessment at a health care facility.

The spike in ENDS-related exposures may reflect an increase in e-cigarette use, lack of familiarity with new products and/or increased media reports highlighting adverse effects.[11,13,31] In parallel with this study, the Canadian Hospitals Injury Reporting and Prevention Program, an injury and poisoning surveillance system fed by the emergency departments of 11 pediatric and 8 general hospitals, reported a sixfold increase in unintentional injuries or poisonings related to vaping products between January 2013 and August 2018;[32] most exposures involved children and adolescents. Minors' ability to legally purchase "non-nicotine" ENDS and novel higher-risk uses such as "dripping" (inhaling e-liquids dropped directly onto heated atomizers) could contribute to higher call volumes among adolescents in Canada.[33]

Our study shows how poison centre data may be used for case-based surveillance. Through the routine collection of information regarding flavours and delivery systems (e.g., single-use e-cigarettes, vape pens, e-pipes), poison centre data could be used to target both product-based and educational interventions. Given the frequency of exposures to ENDS among young children, regulations should aim to minimize harms in this age group. Exposures in toddlers might be prevented through child-resistant packaging, which has been effective in preventing deaths associated with orally administered drugs.[34,35] Prohibiting flavoured e-cigarettes, particularly candy and fruit flavours, could make products less appealing to children. As children were most frequently exposed at home in the current study, education clarifying the contents of e-juices and emphasizing product storage should be offered.

Moreover, given the influence of body weight on toxic effects, sales of highly concentrated nicotine products should be curtailed. The generally accepted lethal dose of nicotine in an adult is 30–60 mg.[36] Extrapolation of the median lethal dose to children is debatable but could be estimated as 0.8–1.0 mg/kg. Given toddlers' low weights, current Canadian proposals to limit the nicotine concentration in e-juices to 66 mg/mL may be insufficiently protective.[37] The low prevalence of major adverse effects in the current study may have been due to the small volumes ingested or to lower-than-labelled nicotine concentrations in ingested products.[11]

Adolescents should be protected through restrictions on sales and advertisements. Young people, who cannot legally buy cigarettes, should also not be permitted to purchase ENDS, including those that are "nicotine-free." In the present study, many people exposed to "low" nicotine or "nicotine-free" solutions still experienced symptoms, consistent with prior studies

showing that labelled concentrations poorly reflect actual nicotine content.[38,39] ENDS should also be subject to marketing restrictions that apply to conventional cigarettes.

Exposures in adults should be addressed through improved packaging and manufacturing standards. A small but important number of exposed adults mistook bottled e-juice for another solution such as eyedrops; this might be remedied with clearer labelling or more distinctive packaging.[10,13] Regulations governing manufacturing, packaging and labelling could also yield more comprehensive data. In our study, the nicotine dosage frequently could not be calculated as product concentrations were not always available.

Limitations

As our study used BC data, the findings may not be generalizable to other provinces. Exposure identification was limited to exposures that led to a call to the poison centre call, whereas the US National Academy of Medicine estimates that less than half of all poisonings lead to poison centre calls.[40] Furthermore, poison centre data may underestimate exposures in urban areas, where increased access to services and expertise may decrease reliance on poison centre services.[41] Our database was not validated against emergency department or other records, or by checking with callers, although a fraction of call records were reviewed and validated by DPIC senior staff. All information was gathered from callers or relevant health care practitioners, and some records contained missing fields. There were variations in coding, and free-text call reports were not standardized. For other fields, there was a default (e.g., the default for place of exposure was "own place of residence"). We mitigated these limitations by validating all fields against verbatim call note information. Lack of follow-up created important limitations in the interpretation of clinical symptoms. Although about half of callers telephoned the poison centre within 10 minutes of the exposure, follow-up was inconsistent. Exposures to e-juices with the highest nicotine concentrations were more likely to be followed. Full clinical trajectories were not recorded and could not be discovered through physician or hospital chart reviews, as patient identifiers were inconsistently noted. This could be addressed through more rigorous follow-up or data linkage.

Conclusion

The availability of poison centre data presented a timely opportunity to study a rapidly changing, relatively novel exposure through detailed exposure records obtained within minutes to hours of the exposure. British Columbia experienced a sixfold increase in ENDS-related calls to the provincial poison centre between 2012 and 2017, driven by ingestions in young children. Electronic cigarettes are relatively novel, and it is important that both the public and health care providers be aware of potential health effects. Nicotine is the primary known hazard, and the amount of nicotine present in e-juices can exceed the labelled concentrations. High-concentration products may present a unique hazard to young children given their low body weight. Moreover, e-juice bottles are sometimes mistaken for other substances. Clear, standardized labelling and child-resistant packaging should be required. As rates of exposure are not declining, increased surveillance (including surveillance across multiple poison centres) may elucidate the ongoing epidemiologic features of exposure.

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