

Pediatric Exposure to E-Cigarettes, Nicotine, and Tobacco Products in the United States

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abstract

OBJECTIVES: To investigate the epidemiologic characteristics and outcomes of exposures to electronic cigarettes (e-cigarettes), nicotine, and tobacco products among young children in the United States.

METHODS: A retrospective analysis of exposures associated with nicotine and tobacco products among children younger than 6 years old was conducted by using National Poison Data System data.

RESULTS: From January 2012 through April 2015, the National Poison Data System received 29 141 calls for nicotine and tobacco product exposures among children younger than 6 years, averaging 729 child exposures per month. Cigarettes accounted for 60.1% of exposures, followed by other tobacco products (16.4%) and e-cigarettes (14.2%). The monthly number of exposures associated with e-cigarettes increased by 1492.9% during the study period. Children <2 years old accounted for 44.1% of e-cigarette exposures, 91.6% of cigarette exposures, and 75.4% of other tobacco exposures. Children exposed to e-cigarettes had 5.2 times higher odds of a health care facility admission and 2.6 times higher odds of having a severe outcome than children exposed to cigarettes. One death occurred in association with a nicotine liquid exposure.

CONCLUSIONS: The frequency of exposures to e-cigarettes and nicotine liquid among young children is increasing rapidly and severe outcomes are being reported. Swift government action is needed to regulate these products to help prevent child poisoning. Prevention strategies include public education; appropriate product storage and use away from children; warning labels; and modifications of e-cigarette devices, e-liquid, and e-liquid containers and packaging to make them less appealing and less accessible to children.



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DOI: 10.1542/peds.2016-0041

Accepted for publication Mar 18, 2016

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PEDIATRICS (ISSN Numbers: Print, 0031-4005; Online, 1098-4275).

WHAT'S KNOWN ON THIS SUBJECT: E-cigarettes were introduced in the US marketplace in 2007. Calls to poison control centers related to this product have increased substantially since then, with most exposures occurring among young children.

WHAT THIS STUDY ADDS: Child exposure to e-cigarettes increased by ~1500% during the 40-month study period. Children exposed to e-cigarettes had 5.2 times higher odds of health care facility admission and 2.6 times higher odds of severe medical outcomes than children exposed to cigarettes.

To cite: Kamboj A, Spiller HA, Casavant MJ, et al. Pediatric Exposure to E-Cigarettes, Nicotine, and Tobacco Products in the United States. *Pediatrics*. 2016;137(6):e20160041

Electronic cigarettes (e-cigarettes) are battery-operated devices that deliver nicotine, flavorings, and other chemicals through an inhaled aerosol. E-cigarette product manufacturers market their product as a safer alternative to traditional cigarettes.¹ E-cigarettes that are marketed without a therapeutic claim are not subject to regulation by the Food and Drug Administration (FDA).²

The e-cigarette industry has expanded since the product entered the US marketplace in 2007, with total sales predicted to approach \$10 billion by 2017.³ This expansion is associated with a rapid rise in the use of e-cigarettes among US adults and adolescents.⁴⁻⁶ Use of e-cigarettes tripled among high school students from 2013 to 2014.⁶

Among the combined e-cigarette and cigarette exposure calls to US Poison Control Centers (PCCs), the proportion of e-cigarette exposures increased from 0.3% in September 2010 to 41.7% in February 2014.² This surge is of concern because more than half of the exposures associated with e-cigarettes occurred among children <6 years and because nicotine can be fatal to young children.^{2,7}

Despite the rapid increases in e-cigarette use and pediatric exposures, an analysis that focuses exclusively and comprehensively on the trends associated with exposures among young children nationally has not been published. To our knowledge, this is the first comprehensive multiyear study of e-cigarette, nicotine, and tobacco exposures among young children using a national database.

METHODS

Data Source

The American Association of Poison Control Centers (AAPCC) maintains the National Poison Data System (NPDS), which captures

data regarding calls to US PCCs on a near real-time basis.⁸ These PCCs receive calls for exposures to a variety of substances through the Poison Help Line 24 hours per day, offer medical advice, and document reported events in the database. Extensive quality control measures are used to ensure the accuracy and completeness of the data collected.⁹ This report is a retrospective analysis of data obtained from the NPDS.

Case Selection Criteria

NPDS data for single substance exposures reported to poison control centers involving nicotine and tobacco products (listed in the Supplemental Table 4) from January 1, 2012, to April 30, 2015, among children <6 years were requested from the AAPCC and analyzed; the AAPCC Micromedex Joint Coding Group's AAPCC generic substance coding system was used to identify these substances.¹⁰

Exposures that occurred outside of the 50 US states and the District of Columbia or occurred at a health care facility (HCF) or "other" location (including nursing home and prison) were excluded from the study. Calls to PCCs in which the outcome was a confirmed nonexposure or an unrelated effect were excluded. Calls for which the reason of exposure was an adverse reaction (to a drug or another substance), abuse, misuse, malicious, unintentional misuse, unintentional therapeutic error, or an unknown reason (both unintentional and otherwise) or calls involving individuals older than 5 years also were excluded.

Study Variables

Study variables included implicated substance, month and year of exposure, state in which the exposure occurred, child age and gender, event scenario, exposure route, exposure site, management site, level of health care received, outcome, duration and

type of clinical effects, and therapy performed.

According to NPDS definitions, (1) minor effects included minimally bothersome symptoms, typically limited to the skin and mucus membranes, which generally resolved rapidly with no residual disability or disfigurement; (2) moderate effects included non-life-threatening symptoms that were more prolonged or systemic in nature than minor symptoms with no residual disability or disfigurement, and usually, some form of treatment is indicated; and (3) major effects included symptoms that were life-threatening or resulted in major disability or disfigurement.⁸ For subanalyses, outcomes were classified as severe (including death, major effects, and moderate effects) and other (including minor and no effect, unable to follow-up, and not followed-up).

The implicated substances were grouped into e-cigarettes (including nicotine device and nicotine liquid), cigarettes, other tobacco products (including chewing tobacco, cigars, dissolvable tobacco, filter tips only, and snuff), and unknown types of tobacco products. States were classified into 4 US regions (West, Midwest, Northeast, and South) per Census Bureau definitions.¹¹ Exposure route was grouped into ingestion, multiple routes with ingestion (including ingestion combined with ≥ 1 of dermal, ocular, inhalation/nasal, other, unknown, and aspiration with ingestion), dermal, inhalation/nasal, ocular, or other (including dermal combined with ocular or inhalation/nasal, otic, and other), and unknown. Exposure site was grouped into residence (including the patient's own or other residence), nonresidence (including public area, restaurant/food service, school, or workplace), and unknown.

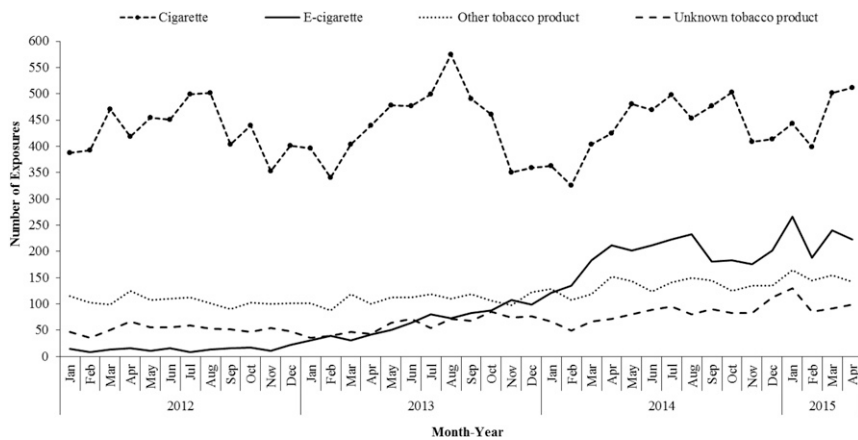


FIGURE 1 Monthly number of nicotine and tobacco product exposures among children younger than 6 years by product type and year, NPDS, January 2012 to April 2015.

Statistical Analysis and Ethical Statement

Data analysis was conducted by using SPSS 21.0 (IBM Corp, Armonk, NY) and SAS 9.3 (SAS Institute, Inc, Cary, NC). Annual and state-specific exposure rates were calculated by using US Census Bureau population estimates.¹² Inspection of the plots (Fig 1) of monthly cigarette and monthly overall tobacco and nicotine product exposures reveals a quadratic seasonal trend that peaks during the summer months. Linear regression with seasonal components (month and month-squared terms) was used to evaluate trends for these exposures. On the other hand, monthly e-cigarette and monthly other tobacco product exposures exhibit a quadratic trend over the entire study period. Linear regression with a quadratic term was used to evaluate trends for these exposures. Simple logistic regression was used to compare various outcome measures between different types of tobacco and nicotine products. One model was used for each outcome measure (severe medical outcomes, HCF admission, and clinical effects) by using types of tobacco and nicotine products as the predictors. Odds ratios (ORs) with 95% confidence intervals (CIs) were calculated by using e-cigarettes as the reference group. Unknown type of

tobacco product was excluded from these analyses. Statistical significance was established at $\alpha = 0.05$. This study was judged to be exempt by the institutional review board of the Research Institute at Nationwide Children's Hospital.

RESULTS

General Characteristics and Trends

From January 2012 through April 2015, the NPDS received 29 141 calls for nicotine and tobacco product exposures among children <6 years, averaging 729 children per month. Cigarettes accounted for 60.1% of the exposures, e-cigarettes for 14.2%, and other tobacco products for 16.4% (Table 1). Chewing tobacco (67.3%) and snuff (25.0%) accounted for most of the other tobacco product exposures. Thirty-nine percent of exposures occurred in the Southern region of the United States (Table 1). Most children were exposed through ingestion (95.5%) or multiple routes including ingestion (2.8%), and only 1.7% through noningestion routes. However, 8.6% of e-cigarette exposures occurred through noningestion routes. The scenario associated with children's access to the nicotine and tobacco products was recorded for 1495 (5.1%) exposures. Of these exposures, the

product was stored within sight of the child in 44.8%, was always left out in 10.2%, and was temporarily open while in use in 8.6% (Table 1).

More than three-quarters (79.6%) of exposed children were <2 years. The median age of exposed children was 1.1 years (interquartile range [IQR] 0.8–1.7). The median age of exposed children varied by substance: 2.0 years (IQR 1.4–2.0) for e-cigarettes, 1.0 years (IQR 0.8–1.3) for cigarettes, and 1.3 years (IQR 1.0–1.9) for other tobacco products. Children <2 years accounted for 44.1% of e-cigarette exposures, 91.6% of cigarette exposures, and 75.4% of other tobacco exposures (Table 1). Boys accounted for 56.1% of all exposures, and the proportion of boys exposed increased with age from 53.4% among children <1 year to 64.3% among children 5 years old.

The monthly number of nicotine and tobacco product exposures, while adjusting for a seasonal trend, increased significantly ($P < .01$) by 73.2% from 563 in January 2012 to 975 in April 2015. This increase was driven by a significant ($P = .04$) quadratic increase in monthly e-cigarette exposures, which rose by 1492.9% from January 2012 (14 exposures) through April 2015 (223 exposures) (Fig 1). During the same time period, there was no significant increase in the monthly number of cigarette exposures adjusted for a seasonal trend ($P = .08$) and no significant quadratic increase in the monthly number of other noncigarette tobacco product exposures ($P = .18$).

The annual rate of nicotine and tobacco product exposure per 10 000 children <6 years increased by 40.3% from 3.0 in 2012 to 4.2 in 2014. The exposure rate was highest in the Midwest region (4.2), and Wyoming was the state with the highest rate (8.3) (Fig 2).

TABLE 1 Characteristics of Nicotine and Tobacco Product Exposures Among Children Younger Than 6 Years, NPDS, January 2012 to April 2015

Characteristics	Type of Nicotine and Tobacco Products				Total, <i>n</i> (%) ^a
	E-cigarette, <i>n</i> (%) ^a	Cigarette, <i>n</i> (%) ^a	Other, <i>n</i> (%) ^a	Unknown, <i>n</i> (%) ^a	
Age, y					
0	367 (8.9)	7715 (44.1)	1145 (24.0)	579 (21.3)	9806 (33.7)
1	1452 (35.2)	8325 (47.5)	2457 (51.4)	1156 (42.5)	13390 (45.9)
2	1591 (38.5)	1198 (6.8)	804 (16.8)	628 (23.1)	4221 (14.5)
3	487 (11.8)	160 (0.9)	222 (4.6)	242 (8.9)	1111 (3.8)
4	161 (3.9)	62 (0.4)	95 (2.0)	80 (2.9)	398 (1.4)
5	67 (1.6)	30 (0.2)	49 (1.0)	36 (1.3)	182 (0.6)
<6 ^b	3 (0.1)	22 (0.1)	6 (0.1)	2 (0.1)	33 (0.1)
Total (row % ^c)	4128 (14.2)	17512 (60.1)	4778 (16.4)	2723 (9.3)	29141 (100.0)
Gender					
Girls	1842 (44.6)	7851 (44.8)	1912 (40.0)	1141 (41.9)	12746 (43.7)
Boys	2278 (55.2)	9632 (55.0)	2861 (59.9)	1578 (58.0)	16349 (56.1)
Unknown	8 (0.2)	29 (0.2)	5 (0.1)	4 (0.1)	46 (0.2)
Total (row % ^c)	4128 (14.2)	17512 (60.1)	4778 (16.4)	2723 (9.3)	29141 (100.0)
US regions					
South	1805 (43.7)	6636 (37.9)	2009 (42.0)	928 (34.1)	11378 (39.0)
Midwest	866 (21.0)	4290 (24.5)	1290 (27.0)	822 (30.2)	7268 (24.9)
West	1149 (27.8)	4016 (22.9)	1036 (21.7)	674 (24.8)	6875 (23.6)
Northeast	308 (7.5)	2570 (14.7)	443 (9.3)	299 (11.0)	3620 (12.4)
Total (row % ^c)	4128 (14.2)	17512 (60.1)	4778 (16.4)	2723 (9.3)	29141 (100.0)
Exposure Site					
Residence	4100 (99.3)	17300 (98.8)	4743 (99.3)	2692 (98.9)	28835 (98.9)
Nonresidence	22 (0.5)	186 (1.1)	31 (0.6)	23 (0.8)	262 (0.9)
Unknown	6 (0.1)	26 (0.1)	4 (0.1)	8 (0.3)	44 (0.2)
Total (row % ^c)	4128 (14.2)	17512 (60.1)	4778 (16.4)	2723 (9.3)	29141 (100.0)
Route of exposure					
Ingestion	3363 (81.5)	17279 (98.7)	4612 (96.5)	2563 (94.1)	27817 (95.5)
Ingestion+ ^d	402 (9.7)	204 (1.2)	121 (2.5)	86 (3.2)	813 (2.8)
Dermal	136 (3.3)	9 (0.1)	11 (0.2)	43 (1.6)	199 (0.7)
Inhalation/nasal	134 (3.2)	6 (0.0)	3 (0.1)	12 (0.4)	155 (0.5)
Ocular	67 (1.6)	3 (0.0)	20 (0.4)	13 (0.5)	103 (0.4)
Other+ ^e	21 (0.5)	4 (0.0)	6 (0.1)	4 (0.1)	35 (0.1)
Unknown	5 (0.1)	7 (0.0)	5 (0.1)	2 (0.1)	19 (0.1)
Total (row % ^c)	4128 (14.2)	17512 (60.1)	4778 (16.4)	2723 (9.3)	29141 (100.0)
Access to product					
Stored within sight of child	100 (41.2)	409 (44.5)	118 (48.2)	43 (49.4)	670 (44.8)
Product always left out	15 (6.2)	95 (10.3)	31 (12.7)	12 (13.8)	153 (10.2)
Product temporarily open and in use	30 (12.3)	61 (6.6)	28 (11.4)	9 (10.3)	128 (8.6)
Child accessed product from purse	8 (3.3)	106 (11.5)		2 (2.3)	116 (7.8)
Product stored inappropriately	19 (7.8)	46 (5.0)	20 (8.2)	5 (5.7)	90 (6.0)
Other+ ^f	71 (29.2)	203 (22.1)	48 (19.6)	16 (18.4)	338 (22.6)
Total (row % ^c)	243 (16.3)	920 (61.5)	245 (16.4)	87 (5.8)	1495 (100.0)

^a Column percentages may not sum to 100.0% due to rounding error.

^b PCCs were unable to obtain the exact age for these cases, but it was known that the child was <6 years old.

^c Row percentages may not sum to 100.0% due to rounding error.

^d Ingestion+ includes the NPDS category of ingestion combined with ≥ 1 other exposure routes.

^e Other+ includes "other," "ocular+dermal," "inhalation/nasal+dermal," and "otic."

^f Other+ includes "other" and single or multiple scenarios with <20 cases.

Management Site, Level of Health Care Received, and Outcome

Approximately three-quarters (75.9%) of exposed children were managed on site (not at an HCF; usually at home), 16.6% were treated/evaluated and released from an HCF, 0.4% were admitted to a noncritical care unit, and 0.2% were admitted to a critical care unit

(Table 2). Compared with children exposed to cigarettes or other tobacco products, those exposed to e-cigarettes were more often referred to an HCF by PCCs (23.4%), already in or en route to an HCF when the PCC was called (21.2%), and treated/evaluated and released (34.8%) (Table 2). Children exposed to e-cigarettes also had higher odds

of being admitted to an HCF than children exposed to cigarettes (OR 5.19, 95% CI 3.60–7.48) or other tobacco products (OR 4.69, 95% CI 2.71–8.12). There were no significant differences in the odds of HCF admission between those exposed to cigarettes compared with those exposed to other tobacco products (OR 0.90, 95% CI 0.52–1.58).

Among all children exposed to nicotine or tobacco products, 35.8% experienced no clinical effects, whereas 1.2% suffered severe outcomes (Table 2). One death to a 1-year-old child occurred associated with nicotine liquid accessed from an open refill container. Children exposed to e-cigarettes (OR 2.60, 95% CI 1.96–3.46) or other tobacco products (OR 3.05, 95% CI 2.35–3.96) had higher odds of having a severe outcome than children exposed to cigarettes. There was no significant difference in the odds of having a severe outcome between those exposed to e-cigarettes and those exposed to other (nonsmoking) tobacco products (OR 0.85, 95% CI 0.85–1.36).

Clinical Effects and Therapies

Among all exposures, 27.5% of children developed ≥ 1 clinical effects related to the exposure. The most common clinical effect was vomiting (22.0%) (Table 3). The odds of having ≥ 1 clinical effect were higher among children exposed to e-cigarettes than among children exposed to cigarettes (OR 1.20, 95% CI 1.11–1.30). Serious clinical effects were less common and occurred among children < 3 years; they included asystole/cardiac arrest ($n = 1$), coma ($n = 6$), single seizure ($n = 6$), and respiratory arrest ($n = 3$). The asystole/cardiac arrest was associated with the fatality; the other serious clinical effects were associated with other nonfatal exposures. Duration of clinical effects was documented for 6242 (21.4%) exposures; of these, 72.6% of the clinical effects persisted for ≤ 2 hours (Table 2).

One or more therapies were performed on 62.6% of the exposed children; dilution/irrigation/wash (56.4%) and food/snack (13.2%) were used most frequently.

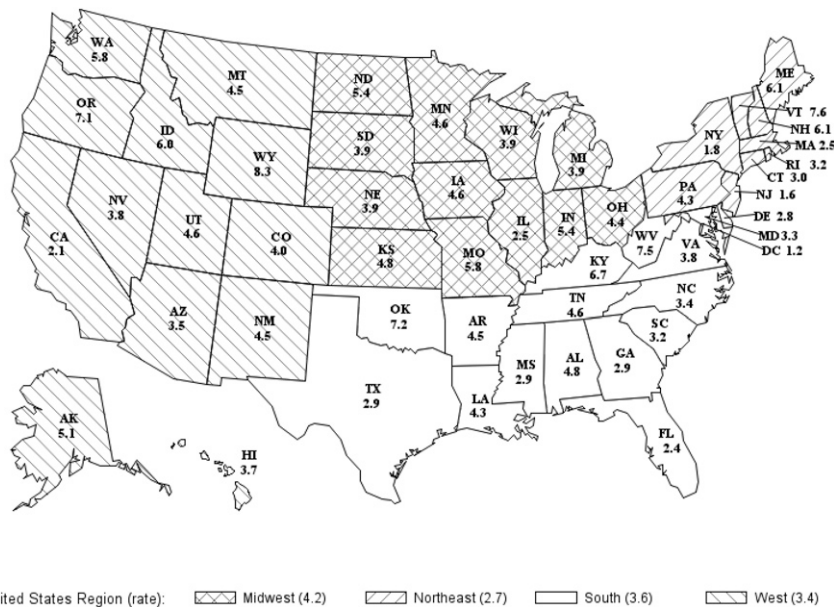


FIGURE 2 Nicotine and tobacco product exposure rate per 10000 children younger than 6 years by state and region, NPDS, January 2012 to December 2014.

DISCUSSION

From January 2012 through April 2015, US PCCs received $> 29\,000$ reports of nicotine and tobacco exposures among children < 6 years. Most of the exposures resulted in minimal toxicity. Although most exposures were to traditional cigarettes, e-cigarette exposures were more often serious than cigarette exposures. Children exposed to e-cigarettes had 5.2 times higher odds of being admitted to an HCF and 2.6 times higher odds of having a severe outcome, compared with those exposed to cigarettes. There was 1 death associated with nicotine liquid exposure.^{13,14} The potential for toxic exposure among young children is heightened by the lack of regulation and standardization of nicotine concentration in e-cigarette cartridges and refill solutions.⁷ E-liquid refill containers are commonly available with nicotine concentrations of 6, 12, 18, 24, and 36 mg/mL (among other concentrations) for direct use, and base concentrations up to 100 mg/mL that are diluted before use.¹⁵ The most common routes associated with

e-cigarette exposure were ingestion alone, multiple routes with ingestion, and dermal, which agrees with a previous study.¹⁶ This is of concern because the greatest risk of toxicity or fatality in the pediatric population is when e-liquid is ingested or absorbed transdermally.⁷

During the study period, the monthly number of exposures associated with e-cigarettes increased by $\sim 1500\%$. This significant increase can largely be attributed to the increasing use of these products. In January 2014, there were 466 e-cigarette brands and 7764 flavors of nicotine liquid available online, having increased by 10.5 e-cigarette brands and 242 flavors per month during the previous 17 months.⁴ From 2010 to 2013, awareness of e-cigarette products increased from 40.9% to 79.7%, while both ever use and current use more than doubled among US adults.⁵ As the household presence of e-cigarettes and their liquid nicotine refill products has increased, so has exposure among young children.¹⁷

Contrary to the trends observed for e-cigarettes, the monthly

TABLE 2 Management Site, Level of Health Care Received, Outcome, and Duration of Clinical Effects Associated With Nicotine and Tobacco Product Exposures Among Children Younger Than 6 Years, NPDS, January 2012 to April 2015

Characteristics	Type of Nicotine and Tobacco Product				Total, <i>n</i> (% ^a)
	E-cigarette, <i>n</i> (% ^a)	Cigarette, <i>n</i> (% ^a)	Other, <i>n</i> (% ^a)	Unknown, <i>n</i> (% ^a)	
Management site					
Managed on site (non-HCF)	2238 (54.2)	14 623 (83.5)	3453 (72.3)	1802 (66.2)	22 116 (75.9)
Patient was referred by PCC to an HCF	972 (23.5)	1508 (8.6)	858 (18.0)	494 (18.1)	3832 (13.1)
Patient already in (en route to) HCF when PCC called	875 (21.2)	1160 (6.6)	397 (8.3)	403 (14.8)	2835 (9.7)
Other	18 (0.4)	54 (0.3)	20 (0.4)	9 (0.3)	101 (0.3)
Unknown	25 (0.6)	167 (1.0)	50 (1.0)	15 (0.6)	257 (0.9)
Total (row % ^b)	4128 (14.2)	17 512 (60.1)	4778 (16.4)	2723 (9.3)	29 141 (100.0)
Level of health care received					
Admitted to HCF	64 (1.6)	53 (0.3)	16 (0.3)	37 (1.4)	170 (0.6)
Admitted to noncritical care unit	40 (1.0)	27 (0.2)	11 (0.2)	26 (1.0)	104 (0.4)
Admitted to critical care unit	24 (0.6)	26 (0.1)	5 (0.1)	11 (0.4)	66 (0.2)
No HCF treatment received	2281 (55.3)	14 844 (84.8)	3523 (73.7)	1826 (67.1)	22 474 (77.1)
Treated/evaluated and released	1435 (34.8)	1926 (11.0)	844 (17.7)	640 (23.5)	4845 (16.6)
Patient lost to follow-up/left against medical advice	218 (5.3)	433 (2.5)	200 (4.2)	134 (4.9)	985 (3.4)
Patient refused referral/did not arrive at HCF	130 (3.1)	256 (1.5)	195 (4.1)	86 (3.2)	667 (2.3)
Total (row % ^b)	4128 (14.2)	17 512 (60.1)	4778 (16.4)	2723 (9.3)	29 141 (100.0)
Outcome					
Severe outcome	77 (1.8)	127 (0.7)	104 (2.2)	47 (1.8)	355 (1.2)
Moderate effect	71 (1.7)	125 (0.7)	103 (2.2)	45 (1.7)	344 (1.2)
Major effect	5 (0.1)	2 (0.0)	1 (0.0)	2 (0.1)	10 (0.0)
Death	1 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.0)
Minor effect	918 (22.2)	3021 (17.3)	1419 (29.7)	530 (19.5)	5888 (20.2)
No effect	1922 (46.6)	6046 (34.5)	1489 (31.2)	963 (35.4)	10 420 (35.8)
Not followed (minimal toxicity)	824 (20.0)	6826 (39.0)	1352 (28.3)	921 (33.8)	9923 (34.1)
Unable to follow (potentially toxic)	273 (6.6)	658 (3.8)	284 (5.9)	183 (6.7)	1398 (4.8)
Not followed (nontoxic)	114 (2.8)	834 (4.8)	130 (2.7)	79 (2.9)	1157 (4.0)
Total (row % ^b)	4128 (14.2)	17 512 (60.1)	4778 (16.4)	2723 (9.3)	29 141 (100.0)
Duration of clinical effects					
≤2 h	648 (65.2)	2393 (76.0)	1107 (72.7)	384 (66.6)	4532 (72.6)
>2 h, ≤8 h	277 (27.9)	545 (17.3)	342 (22.5)	152 (26.3)	1316 (21.1)
>8 h, ≤24 h	37 (3.7)	75 (2.4)	21 (1.4)	21 (3.6)	154 (2.5)
>24 h, ≤3 d	3 (0.3)	5 (0.2)	3 (0.2)	3 (0.5)	14 (0.2)
Anticipated permanent	0 (0.0)	1 (0.0)	0 (0.0)	0 (0.0)	1 (0.0)
Unknown	29 (2.9)	129 (4.1)	50 (3.3)	17 (2.9)	225 (3.6)
Total (row % ^b)	994 (15.9)	3148 (50.4)	1523 (24.4)	577 (9.2)	6242 (100.0)

^a Column percentages may not sum to 100.0% due to rounding error.

^b Row percentages may not sum to 100.0% due to rounding error.

number of exposures among young children to cigarettes did not change significantly over the study period. This is partly due to the decline in cigarette use during the study period, which contrasts with the increase in use of e-cigarettes. During 2002 to 2012, cigarette sales declined from 96.9 to 59.9 cigarette packs per capita, and self-reported current cigarette use also decreased.¹⁸ On the other hand, there was a significant increase in the sale of cigars (from 30.5 to 57.4 cigars per capita), loose tobacco (from 2.5 to 5.6 cigarette pack equivalents per capita), and moist snuff (from 10.6 to 14.6 cigarette pack equivalents

per capita) among US adults from 2002 to 2012,¹⁸ but there was no significant increase in the monthly exposures associated with other tobacco products (primarily chewing tobacco and snuff) during the study period. Although cigarette and other tobacco product exposures among young children did not increase, the continued high frequency of exposure remains an important problem.

Young children are at risk for ingestion because of their curiosity and tendency for oral exploration.^{19,20} As they get older and their taste discrimination matures, they may be more attracted to flavored tobacco products.²¹ Under the Family Smoking

Prevention and Tobacco Control Act, a ban was implemented in 2009 on cigarettes with characterizing flavors other than menthol and tobacco, including fruit- and candy-flavored cigarettes.²² Currently, no such ban exists on e-cigarettes and other tobacco products. The plethora of added flavors, colorful packaging, and candylike appearance associated with e-cigarette devices and their liquid refill products, as well as other tobacco products, may make them more attractive to young children.^{7,23} With increasing mobility and dexterity, toddlers are also able to access and open liquid nicotine refill containers, which currently

TABLE 3 Clinical Effects Associated With Nicotine and Tobacco Product Exposures Among Children Younger Than 6 Years, NPDS, January 2012 to April 2015

Clinical Effect	Type of Nicotine and Tobacco Product				Clinical Effect Total, <i>n</i> (% ^a)
	E-cigarette, <i>n</i> (% ^a)	Cigarette, <i>n</i> (% ^a)	Other, <i>n</i> (% ^a)	Unknown, <i>n</i> (% ^a)	
Cardiovascular					
Tachycardia	62 (1.5)	37 (0.2)	21 (0.4)	33 (1.2)	153 (0.5)
Hypotension	2 (0.0)	1 (0.0)	0 (0.0)	0 (0.0)	3 (0.0)
Bradycardia	1 (0.0)	0 (0.0)	1 (0.0)	0 (0.0)	2 (0.0)
Asystole	1 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.0)
Cardiac arrest	1 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.0)
Dermal					
Pallor	45 (1.1)	113 (0.6)	139 (2.9)	28 (1.0)	325 (1.1)
Erythema/flushed	41 (1.0)	13 (0.1)	7 (0.1)	10 (0.4)	71 (0.2)
Irritation/pain	6 (0.1)	0 (0.0)	0 (0.0)	3 (0.1)	9 (0.0)
Gastrointestinal					
Vomiting	721 (17.5)	3497 (20.0)	1595 (33.4)	596 (21.9)	6409 (22.0)
Nausea	79 (1.9)	278 (1.6)	222 (4.6)	67 (2.5)	646 (2.2)
Oral irritation	48 (1.2)	28 (0.2)	36 (0.8)	8 (0.3)	120 (0.4)
Abdominal Pain	14 (0.3)	18 (0.1)	35 (0.7)	25 (0.9)	92 (0.3)
Diarrhea	5 (0.1)	29 (0.2)	12 (0.3)	7 (0.3)	53 (0.2)
Neurologic					
Drowsiness/lethargy	93 (2.3)	187 (1.1)	183 (3.8)	56 (2.1)	519 (1.8)
Agitated/irritable	42 (1.0)	155 (0.9)	59 (1.2)	27 (1.0)	283 (1.0)
Dizziness/vertigo	15 (0.4)	16 (0.1)	36 (0.8)	10 (0.4)	77 (0.3)
Ataxia	20 (0.5)	19 (0.1)	30 (0.6)	7 (0.3)	76 (0.3)
Tremor	12 (0.3)	26 (0.1)	25 (0.5)	13 (0.5)	76 (0.3)
Confusion	4 (0.1)	6 (0.0)	6 (0.1)	3 (0.1)	19 (0.1)
Seizure (single)	2 (0.0)	1 (0.0)	0 (0.0)	3 (0.1)	6 (0.0)
Coma	4 (0.1)	2 (0.0)	0 (0.0)	0 (0.0)	6 (0.0)
Syncope	1 (0.0)	0 (0.0)	2 (0.0)	0 (0.0)	3 (0.0)
Ocular					
Irritation/pain	94 (2.3)	8 (0.0)	30 (0.6)	16 (0.6)	148 (0.5)
Red eye/conjunctivitis	63 (1.5)	7 (0.0)	19 (0.4)	8 (0.3)	97 (0.3)
Burns	0 (0.0)	1 (0.0)	0 (0.0)	0 (0.0)	1 (0.0)
Respiratory					
Cough/choke	109 (2.6)	462 (2.6)	154 (3.2)	26 (1.0)	751 (2.6)
Cyanosis	3 (0.1)	1 (0.0)	2 (0.0)	0 (0.0)	6 (0.0)
Respiratory depression	2 (0.0)	1 (0.0)	1 (0.0)	0 (0.0)	4 (0.0)
Respiratory arrest	3 (0.1)	0 (0.0)	0 (0.0)	0 (0.0)	3 (0.0)
Abnormal radiograph findings	1 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.0)
Miscellaneous					
Diaphoresis	14 (0.3)	43 (0.2)	47 (1.0)	16 (0.6)	120 (0.4)
Other	56 (1.4)	171 (1.0)	105 (2.2)	30 (1.1)	362 (1.2)
Total Exposures (row %^b)	4128 (14.2)	17 512 (60.1)	4778 (16.4)	2723 (9.3)	29 141 (100.0)

^a Column percentages will not sum to 100.0% because an exposed child may or may not experience ≥ 1 clinical effects.

^b Row percentages may not sum to 100.0% due to rounding error.

generally lack child-resistant closures and often contain potentially lethal amounts of nicotine for a toddler. These developmental changes in taste discrimination, mobility, and dexterity may help explain the slightly greater median age of exposure for e-cigarettes (2.0 years) and other tobacco products (1.3 years) compared with cigarettes (1.1 years).

Prevention

The American Academy of Pediatrics issued 3 policy statements in November 2015 on public policy

to protect children from tobacco, nicotine, and tobacco smoke and electronic nicotine delivery systems.^{24–26} These statements offer recommendations to reduce youth access to e-cigarettes, e-liquid, and related products, including unintentional exposure among young children.

The FDA issued an advanced notice of proposed rulemaking in June 2015, inviting public comment to help inform potential regulatory actions by the FDA with respect

to nicotine exposure warnings and child-resistant packaging for liquid nicotine, nicotine-containing e-liquids, and other tobacco products.²⁷ In response, the AAP and >40 other organizations dedicated to protecting children from harm from tobacco products provided comments that included the following potential regulatory measures: requiring child-resistant packaging and appropriate warning labels for e-cigarette products; requiring child-resistant closures and flow restrictors on e-liquid refill containers; restricting

the use of packaging and labeling attractive to children (eg, images of popular child food products, fruit, and candy are currently used); prohibiting the use of flavors (eg, bubblegum, cotton candy, and popular candy flavors are currently used); limiting the concentration of nicotine in e-liquid and the quantity of e-liquid in refill containers; and ensuring that activation mechanisms and the e-liquid tanks/ compartments on e-cigarette devices are child-resistant.²⁸

Federal legislation, the Child Nicotine Poisoning Prevention Act, was signed into law in January 2016 that requires child-resistant packaging for e-liquid containers.²⁹ Similar legislation has been adopted by 16 states, including 4 states in 2014 and 12 states in 2015.³⁰

In addition to adopting new public policy and modifications of e-cigarettes, e-liquid, and e-liquid refill containers, educational efforts and public awareness may help prevent nicotine exposures among young children. The most frequently reported scenario of access was the product being stored within sight of the child, followed by the product always being left out and the product being temporarily open. Therefore, education of e-cigarette users and child caregivers should emphasize that e-cigarettes and associated products should be stored out of sight and reach of children in a locked location, and should not be accessible

to children when in use. Educating child caregivers about potential clinical effects and outcomes associated with nicotine exposure may help motivate adoption of safety behaviors and aid in identification of symptoms in the event of an exposure. Adults in households with children <6 years should be counseled on vaping cessation and strongly encouraged not to use or store e-cigarettes, e-liquid, and related products in the home.

Limitations

This study has limitations. Our study analyzed NPDS data, which captures only cases voluntarily reported to PCCs, and therefore underestimates the frequency of pediatric exposures associated with nicotine and tobacco products. There is also potential reporting bias among physicians, who might be more inclined to report exposure to a new product, such as e-cigarettes, than a long-established product, such as cigarettes. In addition, the accuracy of reports cannot be completely verified by PCCs or the AAPCC. Data miscoding by PCC poison specialists attending to a call is another potential limitation. Reported exposures do not necessarily represent a poisoning or overdose. Despite these limitations, the NPDS provides a comprehensive, standardized national database on exposures to many substances. It is the most comprehensive data source for the investigation of nicotine and

tobacco exposures among young children in the United States.

CONCLUSIONS

The frequency of exposures to e-cigarettes and nicotine liquid among young children reported to US PCCs is rising rapidly. Children exposed to e-cigarette devices and nicotine liquid are >2.5 times more likely to have a severe outcome than children exposed to cigarettes, and lethal exposure has occurred. Swift government action is needed to regulate these products to help prevent child poisoning. Prevention strategies include public education; appropriate product storage and use away from children; warning labels; and modifications of e-cigarette devices, e-liquid, and e-liquid containers and packaging to make them less appealing and accessible to children.

ABBREVIATIONS

AAPCC: American Association of Poison Control Centers
CI: confidence interval
e-cigarette: electronic cigarette
FDA: Food and Drug Administration
HCF: health care facility
IQR: interquartile range
NPDS: National Poison Data System
OR: odds ratio
PCC: Poison Control Center

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FINANCIAL DISCLOSURE: The authors have indicated they have no financial relationships relevant to this article to disclose.

FUNDING: Ms Kamboj received a research stipend from the National Student Injury Research Training Program at Nationwide Children's Hospital, funded by the Centers for Disease Control and Prevention (grant R49CE002106), and the Child Injury Prevention Alliance while she worked on this study. Interpretations and conclusions in this article do not necessarily represent those of the funding organizations.

POTENTIAL CONFLICT OF INTEREST: The authors have indicated they have no potential conflicts of interest to disclose.

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Pediatrics 2016;137;

DOI: 10.1542/peds.2016-0041 originally published online May 9, 2016;

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