



**RESEARCH BRIEF**

## Evaluating the e-Cigarette Epidemic in US Emergency Departments

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### ABSTRACT

**Background:** Electronic cigarettes (e-cigarettes) are often thought to be a healthier option to cigarette smoking. e-Cigarettes have been found to overheat and explode. e-Cigarette explosions have caused severe trauma and rendered patients in critical conditions. Inadvertent exposures to liquid nicotine products have caused systemic poisoning injuries. We sought to characterize e-cigarette injuries presenting to emergency departments (ED) in 2018.

**Methods:** We analyzed one year of data from the US Consumer Product Safety Commission's National Electronic Injury Surveillance System (NEISS). Patients presenting with injuries associated with e-cigarette products were manually identified for inclusion. We performed descriptive analyses on demographic factors, affected bodily regions, dispositions, locations of occurrence, and mechanisms of injury. By applying sample weights, nationally representative estimates were calculated.

**Results:** A total of 361 667 injury cases were reported in NEISS (2018). We identified 50 e-cigarette injury cases, generating a national estimate of 1739 (95% CI [1333-2148]) patients presenting to US EDs with e-cigarette injuries in 2018. Approximately 1000 pediatric patients (age  $\leq 17$  years) and 700 adult patients (age  $\geq 18$  years) were included. The median age when presenting to the ED was 4 years (interquartile range [IQR], 1-25). Over 85% of injuries occurred at home. Ingestion (55.0%) was the most common mechanism of injury, followed by explosion (35.8%).

**Conclusion:** Children and adults are susceptible to injury from e-cigarette products. Changes in manufacturing standards may prevent injuries from these products.

**Keywords:** e-Cigarette; Vape; Liquid nicotine; Injury surveillance; Epidemiology

### INTRODUCTION

Electronic cigarettes (e-cigarettes) reached the US market in 2007 and have since been perceived as a healthier option to cigarette smoking.<sup>1</sup> These battery-operated devices aerosolize liquid cartridges typically containing propylene glycol, nicotine, tetrahydrocannabinol (THC), or other chemical flavorants for personal use.<sup>2,3</sup> e-Cigarette users activate lithium-ion battery power sources to heat the cartridges and produce vapor for inhalation.<sup>4</sup> While e-cigarettes do avoid the use of matches and lighters associated with traditional cigarettes, e-cigarette use is not without its own immediate risks. e-Cigarettes have been found to overheat, ignite, and explode.<sup>1-5</sup> The process of thermal runaway associated with lithium-ion batteries appears to be at the crux of these failures in e-cigarettes. Given the lack of regulation on e-cigarette manufacturing practices, there could be great variability in the design, quality, and types of materials used by different manufacturers,

potentially leaving consumers more susceptible to injury. Further, some consumers opt for personal modification of their devices such as changing coil resistance or battery voltage.<sup>6</sup> When these products are manufactured or modified poorly, they may be more susceptible to short-circuiting when contacting seemingly innocuous metal objects like keys and coins in users' pockets, further contributing to thermal runaway.<sup>2,6</sup>

e-Cigarette explosions have caused severe trauma and rendered patients in critical conditions. While lithium-ion battery malfunction is not a new phenomenon, e-cigarette-related events may hold the potential for more severe injury.<sup>1</sup> When used or stored, they are kept in close proximity to vital structures of the face or near the groin, respectively.<sup>2,5</sup> These patients often present for emergency treatment with third degree burns to the head, legs, groin, and hands.<sup>2,5</sup> Though e-cigarette explosions are not common, the US Fire Administration reported 195 e-cigarette explosions be-



tween 2009 and 2016 were due to explosions, the majority of which required hospitalization for management of burns around the head and neck.<sup>5</sup>

The increasing prevalence of e-cigarette use among US adolescents and young adults from 2017 to 2019 creates additional concerns for public health.<sup>7,8</sup> In addition to explosion of e-cigarette products, injuries have also occurred following inadvertent exposure to liquid nicotine, particularly among our youth.<sup>9-13</sup> Nicotine exposure in young children is highly concerning when considering the potential neurological insults that may result.<sup>14</sup> Nicotine has several effects on the human body. The binding of nicotinic cholinergic receptors primarily induces sympathetic nervous stimulation, though parasympathetic stimulation and neuromuscular blockade can occur with higher doses.<sup>14</sup> By efficiently penetrating the blood-brain barrier, nicotine can directly affect the brain, clinically manifesting as emesis, seizures, and coma.<sup>14</sup> We sought to explore the extent of e-cigarette injuries and better characterize the e-cigarette epidemic.

## METHODS

### Setting and Design

The National Electronic Injury Surveillance System (NEISS) is a national injury database maintained by the US Consumer Product Safety Commission (CPSC). The CPSC uses NEISS data to aid in surveillance of injuries associated with consumer products and in regulating manufacturing practices and sale of most consumer products in the United States.<sup>15</sup> The CPSC analyzes these data for evidence of the need for product recalls, public awareness campaigns, or product safety standards.<sup>15</sup>

The NEISS collects emergency department (ED) injury data from approximately 100 US hospitals providing continuous emergency care, yielding a statistically valid probability sample of the over 5000 hospital EDs across the nation.<sup>15</sup> Professional NEISS coders review medical records from each participating hospital and collect from patients presenting to EDs with injuries associated with consumer product use. The data collected include patient demographic information, affected bodily regions, diagnoses, dispositions from ED, locations where injury occurred, associated product codes, and text fields for clinical narratives.<sup>16</sup>

We examined e-cigarette product injury incidence and trends across the United States. Per the Code of Federal Regulations and US Department of Health and Human Services, research involving the study of existing records is exempt from human subjects research review if the source is publicly available or if information is recorded in such a manner that subjects cannot be readily identified, directly or through linked identifiers.<sup>17</sup> The NEISS is a publicly available, anonymized database; thus, this research is exempt from institutional review board approval.

### Participants

We analyzed data from all patients with injuries reported by NEISS from January 1, 2018, through December 31, 2018. We did not

restrict inclusion by age, affected bodily region, diagnosis, or specific product codes. Since tobacco products are not within the CPSC's regulatory jurisdiction, NEISS data are not coded specifically for e-cigarette products.<sup>18</sup> The investigators analyzed case narratives to determine if e-cigarette products were involved with injuries. All patients experiencing injury secondary to e-cigarette products were included for analysis.

### Procedures

We identified injuries associated with e-cigarette products by searching clinical narratives for mention of the following terms: "vape," "vapor," "vaping," "cig," "hookah," "e-liquid," "eliquid," "nicotine." We extracted all cases in which the clinical narrative contained at least one of these terms. Two investigators independently reviewed all extracted cases and determined whether e-cigarettes were associated with each case. A third investigator compared the independent reviews and determined if there were any discrepancies in the determination of e-cigarette association. For cases on which the two investigators were not found to agree, a fourth investigator made the final decision independently. The fourth investigator was blinded to prior reviews. The cases found to be associated with e-cigarette products were extracted and included for analysis in this study. Data were cleaned using Microsoft Excel (Microsoft Corporation, 2013).

### Measures

The primary study objective was to characterize the annual incidence of injuries associated with e-cigarette products presenting to EDs across the United States in 2018. Secondary objectives were identifying differences in injury incidence among pediatric and adult patients, mechanisms of injury, affected bodily regions, and dispositions. The CPSC considers NEISS estimates unstable if the estimate is less than 1200, the number of cases is less than 20, or the coefficient of variation exceeds 33%.<sup>16</sup>

### Statistical Analysis

We performed descriptive analyses and applied adjusted sample weights, yielding nationally representative estimates of e-cigarette injuries presenting to US EDs. We analyzed the weighted distribution to determine proportions of e-cigarette injury by age, sex, race, disposition, location of occurrence, bodily region affected, and mechanism of injury.

We assessed normality with both Shapiro-Wilk tests and Q-Q plots. We reported measures of central tendency for nonnormal metrics as medians (interquartile ranges [IQR]). Statistical analyses were performed using jamovi<sup>19</sup> and R (R Core Team, 2019).

## RESULTS

A total of 361 667 injury cases were reported in the NEISS database in 2018, including 50 e-cigarette injury cases. This resulted in a national estimate of 1739 (95% CI [1333-2148]) patients presenting to US EDs with e-cigarette injuries in 2018 (**Table 1**). The



median age of patients when presenting to the ED was 4 years (IQR, 1-25 years). e-Cigarette injuries most frequently occurred among females (55.1%; n=958) and whites (80.0%; 877 of 1097 reporting race) and at home (86.1%; 1248 of 1449 reporting location). Most injuries were systemic and affected all parts of the body. All injuries found to affect all parts of the body were caused by ingestion (n=901, 51.8%). The cases reported as affecting an unknown bodily region were also caused by ingestion (n=56, 3.2%). Explosions and burns typically involved the upper leg (n=317, 18.2%), lower trunk (n=168, 9.7%), pubic region (n=18, 1.0%), and head (n=6, 0.3%).

Among all cases presenting with e-cigarette injuries, 1022 were pediatric patients (age  $\leq 17$  years) and 717 were adult patients (age  $\geq 18$  years) (**Table 2**). The median age of pediatric patients was 1 year (IQR, 1-2 years), and the median age of adult patients was 30 years (IQR, 19-45 years). Ingestion occurred among 93.5% (n=956) of pediatric patients. Explosion occurred among 79.1% (n=567) of adult patients. Pediatric patients experienced 100% of ingestion injuries (n=956), whereas adult patients experienced 91.0% of explosion injuries (n=623). Most e-cigarette injury patients were treated and released (n=1299, 74.7%), though the severity of injuries sustained by 347 (20.0%) patients necessitated further care or hospital admission.

## DISCUSSION

The United States currently lacks robust injury surveillance systems to monitor explosions, burns, and poisonings caused by e-cigarettes. We analyzed nationally representative data to estimate the incidence of e-cigarette injuries in a 1-year period and found over 1700 patients presented to EDs in 2018 with e-cigarette injuries. Approximately half of these injuries were due to ingestion, and one-third were due to explosion of e-cigarette products. These findings parallel trends noted in similar studies regarding e-cigarette explosions and may raise concerns regarding the safety of our youth and e-cigarette product ingestion.

Dohnalek and Harley<sup>1</sup> found a relative decrease in e-cigarette burn and explosion injury incidence from 944 patients in 2016 to 726 patients in 2017. They also found most explosion injuries damaged the upper leg and lower abdomen. Chang and colleagues<sup>9</sup> found the annual incidence of e-cigarette poisoning event in children from 2014 to 2017 to be 1000, 1736, 1416, and 411 injuries, respectively. Nearly all were caused by ingestion.

We used the NEISS to estimate the public health burden of emergency e-cigarette injuries among youth and adults in the United States. Our study is not without limitations. Our study only examined injuries presenting to US EDs; our estimates may be conservative with regard to capturing all e-cigarette injuries since patients experiencing less severe injuries may not have sought emergency care, individuals experiencing injury may not have been able to overcome health care access barriers, and fatal injuries may not have presented to EDs. Additionally, since NEISS cur-

rently does not use product codes specific for e-cigarette products, we may have underestimated the value of e-cigarette injuries presenting to EDs. Further, caution should be taken when interpreting the generalizability of these results, as some reported measures do not meet all the CPSC's stability criteria and may potentially be unreliable.

Other studies<sup>11-13</sup> have utilized data from the National Poison Data System (NPDS) in attempts to characterize the extent of liquid nicotine ingestion and poisoning in children. It was found that most e-cigarette poisonings tracked by poison control centers (PCCs) had minor health effects, with less than 3% of cases having moderate, prolonged, or life-threatening symptoms.<sup>11-13</sup> However, analysis of NPDS data does have limitations. The NPDS findings cannot be used for deriving population estimates, as NPDS is not nationally representative. Further, NPDS data is collected from telephone calls made to PCCs, but not all individuals poisoned by these products call PCCs. It can be reasonably theorized that patients and families experiencing more serious injuries would be inclined to directly seek emergency care rather than waiting to consult a PCC before proceeding.

## PUBLIC HEALTH IMPLICATIONS

The US Food and Drug Administration commissioner and US surgeon general declared youth e-cigarette use an epidemic in 2018.<sup>20,21</sup> e-Cigarette products continue to harm youth and adults across the nation, including in Ohio, though some longer-term health effects are still unknown. The Ohio Department of Health has reported 102 cases, including 96 hospitalizations, of vaping-related lung illnesses across 38 counties, with a median patient age of 25 years (range, 15-65 years).<sup>22</sup> Chronic vaping-related injury surveillance and the recent implementation of Tobacco 21 legislation in Ohio could prove beneficial to the health of our adolescents and adults. Additional state-wide surveillance of acute incidents, like burns and poisonings, may be beneficial for characterizing the immediate harms of e-cigarette products in Ohio. Evidence-based population-level interventions are paramount for addressing public health concerns of this magnitude.

Our findings are likely consistent with the downward trend in e-cigarette explosion and burn incidence from 2016<sup>1</sup> but may be inconsistent with the downward trend in e-cigarette product ingestion and poisoning incidence from 2015. The increase in ingestion injuries from approximately 400 in 2017<sup>9</sup> to 950 in 2018 may raise concerns regarding manufacturing standards and product accessibility. Children may be susceptible to inadvertent nicotine exposure from leakage in open systems and from pods lacking tamper-proof mechanisms in closed systems. Haphazard storage of liquid nicotine and pod refills could also contribute to unintentional exposures. We encourage manufacturers, legislators, and regulatory bodies to reevaluate the efficacy of e-cigarette product manufacturing standards.



Table 1. e-Cigarette Injuries Presenting to US Emergency Departments in 2018

Characteristics	Unweighted N	Weighted N (%)
All [95% CI]	50	1739 [1333, 2148]
Age, median (IQR), years	14.5 (1-29)	4 (1-25)
Sex		
Male	34	781 (44.9)
Female	16	958 (55.1)
Unknown	-	-
Race		
White	22	877 (50.4)
Black	7	107 (6.2)
Other	2	97 (5.6)
Asian	1	16 (0.9)
Unknown	18	642 (36.9)
Bodily region affected		
Elbow	1	75 (4.3)
Knee	1	5 (0.3)
Pubic region	1	18 (1.0)
Head	1	6 (0.3)
Face	1	87 (5.0)
Lower trunk	4	168 (9.7)
Upper leg	14	317 (18.2)
Hand	2	91 (5.2)
Foot	1	75 (4.3)
All parts of body	23	901 (51.8)
Unknown	1	56 (3.2)
Disposition		
Treated and released	35	1299 (74.7)
Treated and transferred	1	87 (5.0)
Admitted and hospitalized	9	194 (11.2)
Held for observation	3	66 (3.8)
Left without being seen	1	79 (4.5)
Unknown	1	17 (1.0)
Location of occurrence		
Home	30	1248 (71.8)
Public	4	145 (8.3)
School	1	56 (3.2)
Unknown	15	292 (16.8)
Mechanism of injury		
Ingestion	24	956 (55.0)
Explosion	22	622 (35.8)
Other	4	161 (9.3)

Unweighted N: raw counts from database

Weighted N: national frequency estimate, statistically weighted

The CPSC considers a national estimate unstable and potentially unreliable when the weighted estimate is less than 1200 or fewer than 20 cases are present. Counts and percentages adjusted for rounding; may differ from reported total.

Table 2. e-Cigarette Injuries Among Pediatric and Adult Patients

Characteristics	Pediatric	Adult
All	1022	717
Age, median (IQR), years	1 (1-2)	30 (19-45)
Mechanism of injury		
Ingestion	956 (93.5)	-
Explosion	56 (5.5)	567 (79.1)
Other	11 (1.1)	150 (20.9)

Pediatric: Patients age ≤17 years when presenting to the ED

Adult: Patients age ≥18 years when presenting to the ED

The CPSC considers a national estimate unstable and potentially unreliable when the weighted estimate is less than 1200.



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