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Samantha J. Sharpe, Lynne M. Rochette and Gary A. Smith
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Pediatric Battery-Related Emergency Department Visits in the United States, 1990–2009

AUTHORS: Samantha J. Sharpe, BS,^{a,b} Lynne M. Rochette, PhD,^a and Gary A. Smith, MD, DrPH^{a,b,c}

^aCenter for Injury Research and Policy, The Research Institute at Nationwide Children's Hospital, Columbus, Ohio; ^bThe Ohio State University College of Medicine, Columbus, Ohio; and ^cChild Injury Prevention Alliance, Columbus, Ohio

KEY WORDS

battery, button battery, children, foreign body, ingestion, injury, insertion

ABBREVIATIONS

CI—confidence interval

ED—emergency department

NBIH—National Battery Ingestion Hotline

NEISS—National Electronic Injury Surveillance System

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Address correspondence to Gary A. Smith, MD, DrPH, Center for Injury Research and Policy, The Research Institute at Nationwide Children's Hospital, 700 Children's Dr, Columbus, OH 43205. E-mail: gary.smith@nationwidechildrens.org

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WHAT'S KNOWN ON THIS SUBJECT: Batteries, especially button batteries, are an important source of pediatric injury. Recent reports suggest that fatal and severe button battery ingestions are increasing.



WHAT THIS STUDY ADDS: An estimated 3289 battery-related ED visits occurred annually among US children <18 years of age, averaging 1 visit approximately every 3 hours. The number and rate of visits increased significantly during the 20-year study period, driven by increases during the last 8 study years.

abstract

OBJECTIVE: To investigate the epidemiology of battery-related emergency department (ED) visits among children <18 years of age in the United States.

METHODS: Using a nationally representative sample from the National Electronic Injury Surveillance System, battery-related ED visits in the United States from 1990 to 2009 were analyzed. Four battery exposure routes for patients were determined from diagnosis codes and case narratives: ingestion, mouth exposure, ear canal insertion, and nasal cavity insertion.

RESULTS: An estimated 65 788 (95% confidence interval: 54 498–77 078) patients <18 years of age presented to US EDs due to a battery-related exposure during the 20-year study period, averaging 3289 battery-related ED visits annually. The average annual battery-related ED visit rate was 4.6 visits per 100 000 children. The number ($P < .001$) and rate ($P = .002$) of visits increased significantly during the study period, with substantial increases during the last 8 study years. The mean age was 3.9 years (95% confidence interval: 3.5–4.2), and 60.2% of patients were boys. Battery ingestion accounted for 76.6% of ED visits, followed by nasal cavity insertion (10.2%), mouth exposure (7.5%), and ear canal insertion (5.7%). Button batteries were implicated in 83.8% of patient visits caused by a known battery type. Most children (91.8%) were treated and released from the ED.

CONCLUSIONS: This study evaluated battery-related ED visits among US children using a nationally representative sample. Batteries pose an important hazard to children, especially those ≤ 5 years of age. The increasing number and rate of battery-related ED visits among children underscore the need for increased prevention efforts. *Pediatrics* 2012;129:1111–1117

There have been many reports of button battery–related injuries to the esophagus, nasal cavity, and ear canal, especially among young children, during the past 2 decades in the United States and other countries.^{1–8} Most button battery ingestions are benign; however, severe complications and even death can occur, especially if a button battery becomes lodged in the esophagus.^{1–7} Recent reports suggest that fatal and severe button battery ingestions are increasing,⁹ and that this trend is associated with the increasing use of 3-V 20-mm lithium button batteries.^{9,10} Button batteries can also cause serious injury if they become lodged in the nasal cavity or external auditory canal.^{6–8,11–13} Complications associated with cylindrical batteries are less common but are also important. Cylindrical cells contain alkaline corrosives that can cause severe burns if the integrity of the battery casing becomes damaged.¹⁴

The most comprehensive studies on battery-related exposures are based on cases reported to the National Battery Ingestion Hotline (NBIH) and US poison control centers.^{9,10,15,16} The National Poison Data System provides an extensive database that can be used for surveillance of battery-related exposures; almost 10 000 exposures were reported among all ages in 2009 alone.¹⁷ However, these studies are based on cases obtained via passive surveillance and therefore are not necessarily representative of all battery-related exposures nationally. Due to the widespread presence of batteries in homes throughout the United States, a nationally representative sample is needed to help quantify the burden of battery-related exposures. Therefore, the goal of this study was to examine the epidemiology of battery-related emergency department (ED) visits by children in the United States using a nationally representative database.

METHODS

Data Source

The National Electronic Injury Surveillance System (NEISS) of the US Consumer Product Safety Commission is a stratified probability sample of ~100 US hospital EDs, including 7 children's hospitals, which were selected from the population of all hospitals with 24-hour EDs having at least 6 beds in the US and its territories.¹⁸ It is updated daily and includes information abstracted from ED medical charts, including patient demographic characteristics and specific incident information such as diagnosis, body region affected, consumer product involved, disposition from the ED, and a brief narrative of the precipitating event. NEISS statistical weights are applied to each case obtained from participating hospitals to provide national estimates for all US hospital EDs. Weights are ratio adjusted annually to accurately reflect the number of ED visits nationwide.^{18,19}

Battery-related ED visits among children <18 years of age from 1990 to 2009 were identified using the NEISS consumer product codes 884 and 892.²⁰ The narrative description for each patient was reviewed, and cases not involving battery-related exposures to internal areas of the body were excluded.

Variables

Cases were divided into 2 age groups for data analysis: ≤5 years and 6 to 17 years. ED disposition codes were used to determine 4 categories: (1) treated and released; (2) transferred to another hospital; (3) admitted; and (4) other (held for <24 hours in the observation unit and left against medical advice). A new variable was created for battery type, with 3 categories identified from NEISS narratives: cylindrical, button, and unknown (not documented or described only as “small”). Button batteries included those described as “button,” “disc,” “watch,” or a description

consistent with the shape and size of a button battery, such as “small and flat.”

Diagnosis codes and case narratives were used to determine 4 exposure route categories: (1) ingestion; (2) mouth exposure; (3) ear canal insertion; and (4) nasal cavity insertion. Mouth exposures included cases in which the presence of a battery in the oral cavity resulted in a chemical burn. Ingestions included cases in which an intact battery was swallowed. Due to small sample size, national estimates for 8 cases of battery insertion into the vagina or rectum could not be computed; therefore, these cases were excluded from the study, resulting in a final sample size of 2338 actual cases, which were used to calculate national estimates.

Statistical Analysis

Data were analyzed using SPSS 17.0 (SPSS Inc, Chicago, IL), Epi Info 6.0 (Centers for Disease Control and Prevention, Atlanta, GA), SUDAAN 9.0 (Research Triangle Institute, Research Triangle Park, NC), and SAS 9.1 (SAS Institute, Inc, Cary, NC) statistical software. Statistical weights were applied during analyses to produce national estimates. Numbers reported in this article are national estimates unless noted otherwise. The Consumer Product Safety Commission considers an estimate to be unstable when the number of sample observations is <20; therefore, national estimates and statistical calculations were not made for these small groups. Statistical analysis included the calculation of relative risks with 95% confidence intervals (CIs), using stratum and primary sampling unit variables to account for the complex survey design of the NEISS sample. Missing values were not included in analyses. Linear regression was used to assess the statistical significance of secular trends by using $\alpha = .05$. Rates of ED visits were calculated by using 1990–2009 annual population estimates

obtained from the US Census Bureau.^{21,22} The institutional review board of The Research Institute at Nationwide Children's Hospital (Columbus, OH) approved this study.

RESULTS

All Battery-Related ED Visits

There were an estimated 65 788 (95% CI: 54 498–77 078) battery-related ED visits among children <18 years of age during 1990–2009, yielding an average of 3289 visits annually or 1 visit every 2.66 hours nationally. The average annual battery-related ED visit rate for children <18 years of age was 4.6 per 100 000 children (Table 1). The mean patient age was 3.9 years (95% CI: 3.5–4.2; median: 3 years). More than three-fourths (78.5%) of patients were ≤5 years of age, and 60.2% were boys (39 517 of 65 673). Patients 1 year of age had the greatest number of visits among any single-year age group (13 742 of 65 788 [20.9%]) (Fig 1).

Among children aged <18 years, there was a significant increase in the number ($m = 153.859$; $P < .001$) and rate ($m = 0.178$; $P = .002$) of battery-related ED visits from 2591 visits (4 per 100 000 children) in 1990 to 5525 visits (7.4 per 100 000 children) in 2009 (Fig 2). These trends were driven by substantial increases in the number ($m = 389.321$; $P < .001$) and rate ($m = 0.509$; $P < .001$) during the last 8 years (2001–2009) of the study. The significant increase in the number ($m = 116.607$; $P = .003$) and rate ($m = 0.418$; $P = .007$) of ED visits was also observed for children ≤5 years of age, from 2255 visits (10 per 100 000) in 1990 to 4872 visits (19.1 per 100 000 children) in 2009. These trends were also driven by significant increases in the number ($m = 440.655$; $P < .001$) and rate ($m = 1.639$; $P < .001$) during the last 8 study years. There was no seasonal variation in the number of ED visits per month.

Of the estimated 16 246 cases where the battery's intended use was mentioned in

TABLE 1 Demographic Characteristics of Children Receiving ED Treatment of Battery-Related Exposures in the United States, 1990–2009

Characteristic	Actual Sample	National Estimate	95% CI	% National Estimate	Rate per 100 000 Children
Age, y					
0–5	1842	51 618	42 800–60 436	78.5	10.8
6–17	496	14 170	11 493–16 846	21.5	1.5
Gender					
Boy	1388	39 517	32 894–46 141	60.2	5.4
Girl	948	26 156	21 881–30 431	39.8	3.8
Total	2338	65 788	54 498–77 078	100.0	4.6

Gender information was missing for 2 actual cases.

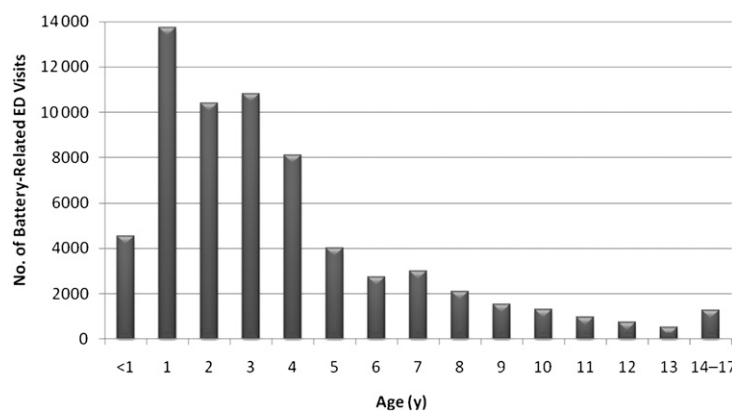


FIGURE 1

Number of battery-related ED visits among children aged <18 years according to age group in the United States, 1990–2009.

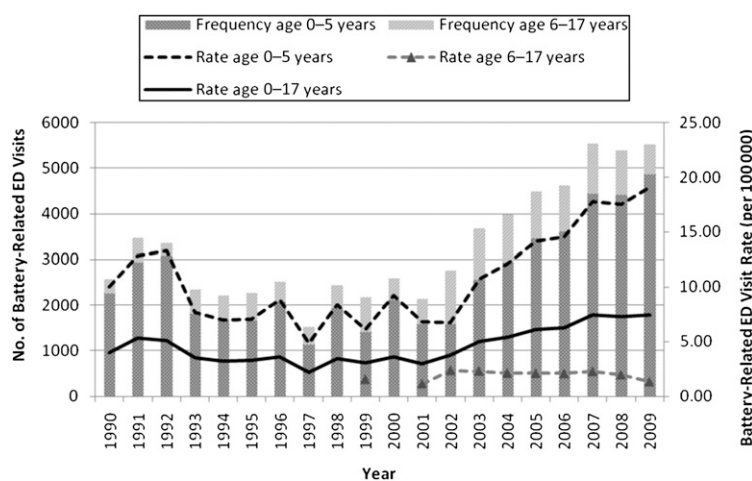


FIGURE 2

Annual number and rate of battery-related ED visits according to age group and year in the United States, 1990–2009. Due to small sample size, national estimates for the age group 6 to 17 years were unstable for the years 1990–1998 and 2000; therefore, rates for these years are not represented.

the narrative (24.7% of cases) across all years of the study, 29.0% involved toys/games, 15.9% hearing aids, 13.7% watches, 12.4% calculators, 8.8% flashlights, 5.5% remote controls, and 14.7%

other. When only considering the estimated cases during the last 8 years of the study (6905 of 29 139 cases), toys/games (27.3%), hearing aids (17.0%), and watches (13.9%) still predominated,

but flashlights (13.6%) and remote controls (9.8%) exceeded calculators (7.0%). Among the estimated 42 655 cases for which battery type was described (64.8% of cases) across all years of the study, 83.8% (35 730 of 42 655) were button batteries and 16.2% (6925 of 42 655) were cylindrical batteries; during the last 8 study years, the distribution was similar: 85.4% button and 14.6% cylindrical batteries. Among all patients, 91.8% were treated and released from the ED, 4.3% were admitted, 3.0% were transferred to another hospital, and 0.8% had other dispositions. The percentage of patients who were treated and released decreased from 93.9% to 90.1% from the first 12 years to the last 8 years of the study, and the percentage of patients who were admitted increased from 3.6% to 5.0%. No fatalities were reported; however, the NEISS does not capture fatalities well. Girls were 1.71 times (95% CI: 1.11–2.63) more likely to be admitted than boys.

Battery ingestion accounted for 76.6% of battery-related ED visits, followed by nasal cavity insertion (10.2%), mouth exposure (7.5%), and ear canal insertion (5.7%). Ingestion accounted for 77.2% (39 871 of 51 618) of battery-related visits among ≤ 5 -year-olds and 74.1% (10 496 of 14 170) of battery-related visits among 6- to 17-year-olds (Fig 3). The next most common battery exposure route for children ≤ 5 years of age was nasal cavity insertion (6466 of 51 618 [12.5%]); however, ear canal insertion was the second most common battery exposure route for children 6 to 17 years of age (2431 of 14 170 [17.2%]). Due to small sample sizes for some ages, Fig 4 displays unweighted frequencies for battery-related ED visits for all exposure routes to illustrate the difference in age distributions.

Ingestion

There were an estimated 50 367 (95% CI: 41 273–59 461) ED visits for battery

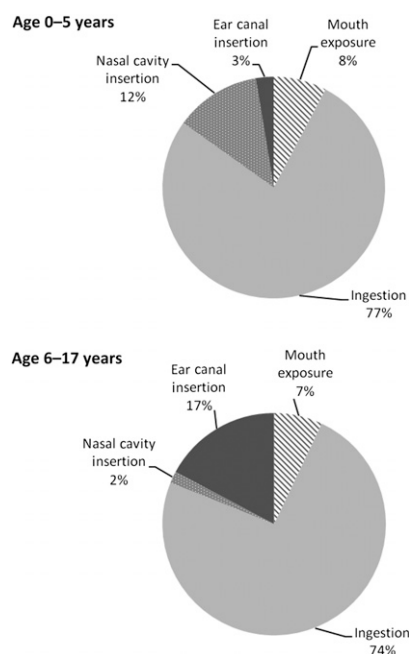


FIGURE 3 Battery exposure route according to age group in the United States, 1990–2009.

ingestions among children < 18 years of age (mean: 3.8 years; 95% CI: 3.3–4.2; median: 3 years). Most (79.2%) children were aged ≤ 5 years, and 58.8% were boys (29 571 of 50 296). The type of battery ingested was not specified for one-third (33.6%) of cases. Among cases for which battery type was described, 85.4% (28 563 of 33 433) involved a button battery. It was documented in 18 unweighted cases that the button battery lodged in the esophagus.

Among children < 18 years of age, there was a significant increase in the number ($m = 129.559$; $P < .001$) and rate ($m = 0.153$; $P = .002$) of ED visits for battery ingestions from 1507 visits (2.3 per 100 000 children) in 1990 to 4916 visits (6.6 per 100 000 children) in 2009. Among children aged ≤ 5 years, the number ($m = 96.386$; $P = .009$) and rate ($m = 0.346$; $P = .017$) of ED visits for battery ingestions also increased significantly, reaching 4316 visits (16.9 per 100 000 children) in 2009. When evaluating button batteries alone, a significant increase in the number of ED visits for ingestion was observed among

children aged < 18 years ($m = 57.909$; $P = .024$), from 1301 visits in 1990 to 2785 visits in 2009. Although a statistically significant trend in ED visits for button battery ingestions was not observed in the subgroup of children ≤ 5 years of age ($m = 40.082$; $P = .117$) during the 20-year study period, there was a statistically significant increase during the last 8 study years ($m = 228.036$; $P = .001$). The 2009 ED visit rate for ingestion of button batteries among children aged < 18 years was 3.7 per 100 000 children and 10.1 among ≤ 5 -year-olds.

Mouth Exposure

There were an estimated 4959 (95% CI: 4293–5625) ED visits for battery-related mouth exposure among children aged < 18 years (mean age: 3.7 years; 95% CI: 3.1–4.3; median: 3 years). The majority (79.9%) of patients were ≤ 5 years old, and 67.1% were boys (3298 of 4916). The type of battery related to exposure was not specified in 54.8% of cases. Among cases for which the battery type was described, 91.5% (2050 of 2240) involved a cylindrical battery. The average annual ED visit rate for battery-related mouth exposure was 0.35 per 100 000 children aged < 18 years.

Ear Canal Insertion

There were an estimated 3748 (95% CI: 3206–4290) battery-related ED visits for ear canal insertion among children aged < 18 years (mean age: 6.7 years; 95% CI: 6.1–7.4; median: 7 years). The majority (64.8%) of patients were 6 to 17 years old, and 72.1% were boys (2704 of 3748). Patients 6 to 17 years old were 6.72 times (95% CI: 3.80–11.89) more likely to have an ED visit caused by ear canal insertion than patients aged ≤ 5 years. Among the estimated 2807 cases for which battery type was described (74.9% of cases), almost all (2802 of 2807 [99.8%]) involved a button battery. The average annual ED visit rate

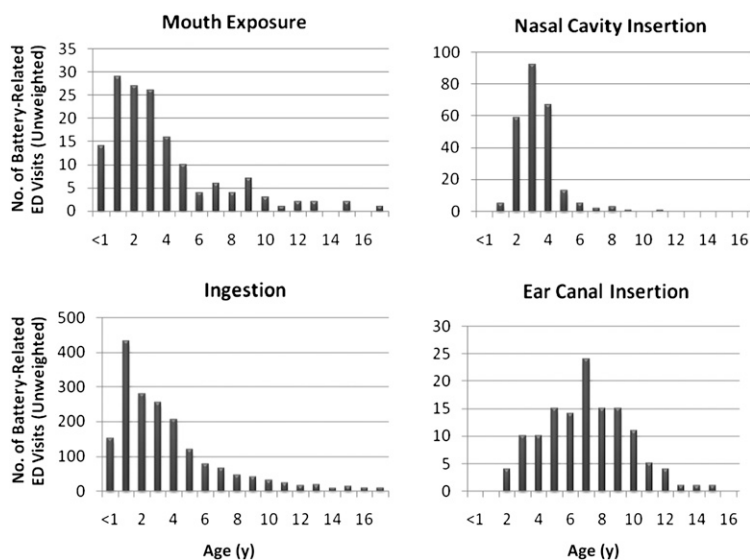


FIGURE 4

Number of unweighted battery-related ED visits among children <18 years of age according to exposure route and child age in the United States, 1990–2009. Numbers represent actual unweighted cases rather than national estimates due to small sample size for some age groups.

for ear canal insertion of button batteries was 0.20 per 100 000 children aged <18 years.

Nasal Cavity Insertion

There were an estimated 6713 (95% CI: 5296–8130) battery-related ED visits for nasal cavity insertion among children aged <18 years (mean age: 3.3 years; 95% CI: 3.1–3.5; median: 3 years). The great majority (96.3%) of patients were ≤ 5 years old, and 58.8% were boys (3945 of 6713). Among the estimated 4176 cases (62.2% for which battery type was described, all involved a button battery. The average annual ED visit rate for nasal cavity insertion of button batteries was 0.29 per 100 000 children aged <18 years.

DISCUSSION

From 1990 to 2009, there were almost 66 000 battery-related ED visits among children aged <18 years in the United States, which averages ~ 3300 visits per year or a visit approximately every 3 hours nationally. The number and rate of these visits increased significantly during the study period, which

was primarily driven by a significant increase in battery-related ED visits among children aged ≤ 5 years.

In this study, button batteries were implicated in >80% of all ED visits for which battery type was specified. These findings may be due in part to the increasing use of button batteries to power a wide range of electronics and their increased availability in the home. When the intended use of the battery was known, most involved toys/games, hearing aids, watches, calculators, flashlights, and remote controls. This agrees with the top 6 categories identified by Litovitz et al,¹⁰ who reported that 61.8% of batteries ingested by young children were obtained directly from the product by the child. Preventing children from accessing button batteries from these sources would be a key step toward reducing battery exposure and battery-related injury. Battery compartments of all household devices should be taped securely shut by child caregivers. Manufacturers should design these battery compartments so that they require a screwdriver or other tool to be opened or are secured with a child-resistant locking

mechanism.¹⁰ Product safety standards should incorporate this stipulation for all button battery–powered household devices, regardless of whether they are intended for use by children.

Ingestion

The most frequent exposure route for battery-related ED visits was ingestion of the battery. The majority of ingestions occurred among children aged ≤ 5 years, which agrees with previous findings.¹⁰ Young children have a natural tendency to explore their environment by placing batteries and other objects into their mouths. Child caregivers should ensure that batteries are stored out of the reach of children and discarded properly. Education of caregivers and product warning labels may provide some benefit but should be coupled with more effective passive prevention strategies.²³ Manufacturers should ensure that battery packaging is child resistant.¹⁰

This study demonstrated a significant increase in the frequency and rate of ED visits due to battery ingestions among children. Most batteries will pass through the gastrointestinal tract spontaneously without adverse consequences. However, severe morbidity and fatality can occur if the battery lodges in the esophagus.^{9,10} When battery type was known in this study, >85% of ingestions involved a button battery. Cases reported to the NBIH indicated a somewhat higher proportion (94%) of button battery ingestions among all ages.¹⁰ The lower proportion in this study may be because the NBIH, unlike the NEISS, obtains case reports through passive surveillance and is not restricted to only those treated in hospital EDs. The lower proportion of button battery ingestions also may be because the age groups being reported were different and the type of battery was unspecified in approximately one-third of cases in this study. Nevertheless,

this study demonstrated a significant increase in ED visits due to button battery ingestion among children aged <18 years, and when only the last 8 years of the study period are considered, also among children aged ≤ 5 years. Previous research indicates that outcomes from button battery ingestion are worse among children <4 years of age⁹; therefore, prevention efforts focused on young children are important. Product redesign is a potential future solution to reduce these button battery ingestion-related injuries.

If a button battery lodges in the esophagus, surrounding tissue injury can occur in just 2 hours by several mechanisms, listed in order of importance: (1) when placed in a conductive medium, a button battery gives rise to an external current, causing electrolysis of tissue fluids and the generation of hydroxide at the battery's negative pole; (2) leakage of alkaline electrolyte from the battery causing liquefactive necrosis; and (3) pressure necrosis.^{2,9,10,16} Recent evidence points to the first mechanism as the most important, especially for 20-mm lithium batteries, which do not contain an alkaline electrolyte and generate more current because they have twice the voltage and higher capacitance compared with other button batteries.¹⁰ Delayed complications include esophageal perforation, esophageal stricture, vocal cord paralysis due to recurrent laryngeal nerve damage, and development of tracheoesophageal or aortoesophageal fistulas that can lead to exsanguination and death.^{1-5,9,10,24} Litovitz et al⁹ reported an alarming 6.7-fold increase from 1985 to 2009 in the percentage of button battery ingestions with severe and fatal outcomes, and found that outcomes were worse among children <4 years old. Because button batteries may be mistaken for a coin, electrocardiogram electrode, or other external object on a chest radiograph, disk-shaped objects should be

carefully examined for features such as diameter and a double rim to prevent delays in diagnosis.

Mouth Exposure

The majority of children who experienced chemical burns to the mouth were aged ≤ 5 years, with a mean age of 3.7 years. Cylindrical batteries were responsible for >90% of cases with known battery type. Although injury from cylindrical batteries is much less likely than with button batteries,¹⁴ chewing on cylindrical batteries can damage the battery casing, which may result in injury.

Ear Canal Insertion

The majority of battery-related ED visits caused by ear canal insertion was observed among children 6 to 17 years of age, with a mean age of 6.7 years. In fact, patients 6 to 17 years old were 6.7 times more likely to have an ED visit due to ear canal insertion than patients ≤ 5 years old. This is the only exposure route predominately observed among older children. A similar average age for ear canal insertions of other foreign body types, such as beads and paper, has been reported.^{25,26} In this study, almost all cases of ear canal insertion with known battery type involved a button battery. Previous case reports have illustrated that severe complications can arise from button battery lodgment inside the ear canal.^{7,13} This underscores the need for parental supervision and proper storage of batteries even in households with older children.

Nasal Cavity Insertion

The majority of battery-related ED visits for nasal cavity insertion was observed among children aged ≤ 5 years, with a mean age of 3.3 years. All cases with specified battery type involved button batteries. Previous case reports have shown that button battery lodgment in

the nasal cavity can cause serious complications.^{6,8,11-13} Research from Europe identified a median age of 3 to 4 years for pediatric nasal cavity insertions of many foreign body types, such as seeds, clips, and batteries, and that parental supervision was present for 38% of the incidents.²⁴ Thus, supervision alone is not enough to prevent nasal cavity insertions; passive prevention strategies are also needed.

Limitations

This study has several limitations. The NEISS database only contains records of patients treated in EDs; therefore, this study underestimates the true number of pediatric battery-related exposures. This study may not be representative of patients treated at other types of health care facilities or those who were untreated. NEISS narratives contained little information documenting the size (diameter), discharge state, and chemical system of the battery, which limited the determination of specific battery types with the highest likelihood of causing morbidity. The NEISS does not capture fatalities well, nor does it contain information regarding diagnostic workup (eg, radiography), treatment (eg, endoscopy), or outcome after patients leave the ED. Data regarding exposure to risk for rate calculations are unknown; therefore, US census data were used for calculation of population-based ED visit rates, which is an acceptable alternative method. This study was unable to determine whether the observed increase in pediatric battery-related ED visits was due to increased exposure to batteries, increased severity of the exposures, or changes in health care-seeking behavior by child caregivers due to increased public knowledge of battery-related injury.

CONCLUSIONS

This study evaluated battery-related ED visits by US children using a nationally representative sample. Batteries pose

an important hazard to children, especially those aged ≤ 5 years. Primary prevention of battery exposures is critical

because of the limited effectiveness of medical interventions once tissue damage has occurred. The increasing

number and rate of battery-related ED visits among children underscore the need for increased prevention efforts.

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Samantha J. Sharpe, Lynne M. Rochette and Gary A. Smith

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