Magnet Injuries in Children: An Analysis of the National Poison Data System from 2008 to 2019

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Objective To examine, using the National Poison Data System (the data warehouse for poison control centers in the US), magnet foreign body injuries in pediatric patients. We sought to report demographic data, outcome data, and case trends between 2008 and 2019.

Study design We conducted a retrospective analysis of the National Poison Data System for patients younger than 19 years of age with a magnet "exposure," which poison centers define as an ingestion, inhalation, injection, or dermal exposure to a poison.

Results A total of 5738 magnet exposures were identified. Most were male (3169; 55%), <6 years old (3572; 62%), with an unintentional injury (4828; 84%). There were 222 patients (3.9%) with a confirmed medical "effect," defined as signs, symptoms, and clinical findings not including therapeutic interventions (eg, endoscopy). There was a 33% decrease in cases from 418 (2008-2011) to 281 per year (2012-2017) after high-powered magnet sets were removed from the market. Calls subsequently increased 444% to 1249 per year (2018-2019) after high-powered magnet sets re-entered the market. Cases from 2018 and 2019 increased across all age groups and account for 39% of magnet cases since 2008.

Conclusions Significant increases in magnet injuries correspond to time periods in which high-powered magnet sets were sold, including a 444% increase since 2018. These results reflect the increased need for preventative or legislative efforts. *(J Pediatr 2021;232:251-6)*.

There are approximately 100 000 cases of foreign body ingestions each year in the US, roughly 80% of which occur in children younger than 12 years of age.[1,2] The majority are unintentional and occur in those younger than the age of 5 years.[1] Although many foreign body ingestions of products such as coins are benign and pass spontaneously through the gastrointestinal tract, others carry significant risk. High-powered magnets are among the most dangerous ingestion hazards in children.[2]

High-powered magnets are made from rare earth metals such as neodymium and are sold in sets of hundreds as desk toys or novelty items. They are small (<5 mm), shiny, and powerful; most are 5-30 times stronger than ferrite refrigerator magnets.[3-5]

Magnets attract to each other across tissue, cutting off blood supply to the bowel and causing tissue necrosis, perforation, fistula formation, obstruction, sepsis, or death.[2,4,6-18] Children who ingest these magnets may be asymptomatic at first but often develop nonspecific symptoms such as abdominal pain, vomiting, or fever. High-powered magnet injuries can be difficult to distinguish from other gastrointestinal illnesses, particularly in preverbal children, without imaging.[12] Numerous professional health organizations, including the American Academy of Pediatrics, American College of Medical Toxicology, Centers for Disease Control and Prevention, and North American Society for Pediatric Gastroenterology, Hepatology and Nutrition recognize the dangers of high-powered magnet products and recommend immediate medical consultation if ingested or internalized.[2,5,19,20]

An estimated thousands of injuries have occurred since high-powered magnets entered the US market in the early 2000s in children's toys, with the vast majority occurring after high-powered magnet sets were first introduced as desk toys in 2009.[4,6,7,21-23] Trends in magnet injuries have fluctuated, corresponding to time periods in which, following federal action and court decisions, high-powered magnets were on or off the market.[21,24-28]

To date, these analyses have used the National Electronic Injury Surveillance System (NEISS), a dataset maintained by the Consumer Product Safety Commission (CPSC). NEISS only captures data from emergency department visits and does not identify patients treated in other healthcare settings, such as urgent

AAPCC	American Association of Poison Control Centers
CPSC	Consumer Product Safety Commission
NEISS	National Electronic Injury Surveillance System
NPDS	National Poison Data System
PCC	Poison control center

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care centers, clinics, or hospital wards.[29] Further, NEISS does not contain outcome data to ascertain the effects of injury. For these reasons, we sought an alternate source.

We aimed to identify magnet case trends and outcomes over a 12-year period using the National Poison Data System (NPDS), a database of patient injury cases called into the American Association of Poison Control Centers (AAPCC). The current study presents the number of magnet-related calls within the NPDS from 2008 through 2019 and provides national outcome data on magnet injuries.

Methods

The AAPCC is a consortium of 55 poison control centers (PCCs) from all 50 states and US territories.[30] The network of regional PCCs in the US offer free, confidential medical advice 24 hours per day by telephone through the Poison Help Line. During case management, measures such as exposure, age, sex, substance, clinical effects, therapies, and medical outcomes are documented by the healthcare professional answering each call. Information gathered from these calls, and follow ups, are uploaded in real-time to the NPDS.

This study was deemed as exempt by the institutional review board at Nationwide Children's Hospital. Institutional review board approval was obtained from Albert Einstein College of Medicine.

NPDS Terminology

Poison centers use standardized nomenclature for every call type regardless of the injury mechanism. The term "exposure," for example, is used by PCCs to designate an individual case or patient exposed to a poison or injurious product. The term is route neutral, meaning it captures cases of ingestion, inhalation, injection, or dermal exposure. "Effect" describes reported signs, symptoms, and clinical findings associated with an exposure.

Patient "outcome" is recorded only if follow up continues and the outcome can be documented with reasonable certainty. Outcomes are organized into groups: (1) "no effect;" (2) "minor effect" involving the development of quickly-resolving, minimally bothersome symptoms; (3) "moderate effect" entailing non–life-threatening symptoms that were more pronounced, prolonged, or systemic in nature and typically require treatment; (4) "major effect" including symptoms that were life-threatening or resulted in significant disability; or (5) "death."[1] Consistent with previous NPDS studies, an additional outcome category was created for analytic purposes only: "serious outcome." This categorization was created by combining categories moderate (3), major (4), and death (5).[31,32] Importantly, clinical effects and outcomes do not take into account necessary interventions (eg, endoscopy or surgery).

In circumstances in which it is inappropriate or impossible to follow a patient to a reasonable medical outcome, the following are coded: (6) "not followed, judged as nontoxic exposure," in which patients are not followed because there was unlikely to be a clinical effect (eg, swallowing one high-powered magnet or a low-powered magnet); (7) "not followed, minimal clinical effects possible," in which the patient is not followed because the exposure will result in minimal toxicity of a trivial nature; (8) "unable to follow, judged as a potentially toxic exposure," in which the patient was lost to follow up and the exposure was significant and may have resulted in toxic manifestations; (9) "unrelated effect," in which the exposure was not judged to be responsible for the effect; (10) "confirmed nonexposure," in which there is reliable evidence that the exposure never occurred and that symptoms were unrelated to the exposure (eg, no identifiable object on radiograph). For purposes of analysis, categories #6 and #7 were combined into 1 category: "not followed."

Lastly, "unintentional" exposures were defined as those resulting from an unforeseen or unplanned event (eg, magnet ingestion in a toddler) and "intentional" exposures resulted from a purposeful action (eg, a teen swallowed the magnet while mimicking a facial piercing).

Case Selection Criteria

NPDS was queried for all human exposures from January 1, 2008, through October 31, 2019, with a single-substance exposure (ie, only magnet(s) ingestion without other foreign bodies or substances), substance code as magnet (AAPCC product code 6811841), and patients 0-19 years of age. There was not enough granularity to determine each object within multiple foreign body exposures; therefore, only single substance (ie, magnet) exposures were included. Age groups were classified by single years of age and were recoded into composite age groups (0-5 years, 6-12 years, and 13-19 years), which uses the standard age groupings within the NPDS.

The time frame was selected to span the introduction of high-powered magnet sets in the US and examine exposure trends following related court decisions. Data were stratified a priori into 3 time periods that correspond to events effecting the production and sale of high-powered magnet sets: 2008-2011, injuries from high-powered magnets in children's toys and the introduction of high-powered magnet desk toys; 2012-2017, the removal of high-powered magnet sets from the market by the CPSC; and 2018-2019, the return of high-powered magnet sets to the market.

Statistical Analyses

Descriptive statistics with percentage or SD were calculated, as applicable. Total exposures in 2019 were estimated proportionally using data up to October 31 (x cases/304 days = y cases/365 days). Further analysis of reported patient means by month was conducted to identify any seasonality trends using Kruskal–Wallis test. Tests of means were conducted by using the Mann–Whitney *U*/Wilcoxon (Kruskal–Wallis) for a 2-sample test. Statistical significance was established at $\alpha = 0.05$ and 95% CIs were provided for all hypothesis testing. Epi Info7 (Centers for Disease Control and Prevention) was used to conduct data analysis.

Results

A total of 5738 pediatric magnet exposures were reported to US PCCs between 2008 and 2019, with 39% of cases occurring between 2018 and 2019. The mean age was 5.2 years (SD = 4.1), ranging from 5 months to 19 years old. The majority were male (55.2%) and <6 years old (62.3%) (**Table I**). Approximately one-half (48.4%) of patients were treated at a hospital or other healthcare facility, such as a pediatrician's office, and 48.7% were managed at a non-healthcare site such as home, workplace, or school. The majority of patients were not followed (45.6%) or were unable to be followed (12.8%) for outcome information. In addition, 30.4% of patients were found to have no medical effect and 6.4% had a confirmed nonexposure. Most injuries were unintentional (84.1%), which was greatest in the younger than 5-year age group (99.3%) and lowest in the 13- to 19-year group (41.1%). Conversely, the majority (56.8%) of cases in the 13- to 19-year group were intentional in nature.

Cases decreased by 33% ($P < .05$) from 2012 to 2017 compared with from 2008 to 2011 (**Table II**). However, the annual number of patients increased 490% after 2017, from 322 in 2017 to 1580 estimated cases (1316 actual) in 2019 (**Figure 1**). This includes a 420% increase in patients treated in the hospital for magnet ingestions: 165 in 2017 and 693 in 2019 (**Figure 1**). When we compared 2018 to 2019 and 2012 with 2017, there was a 444% ($P < .05$) increase in overall magnet injuries and a 355% ($P < .05$) increase in hospital-treated injuries (**Table II**). These increases occurred across all age groups but were most prominent in children 0-5 years and 6-12 years (**Figure 2** [available at www.jpeds.com] and **Table II**). There was also a 500% increase ($P < .05$) in serious outcomes when comparing before and after 2017: a mean of 2 serious outcomes per year between 2008 and 2011 (SD 1.09, 95% CI 1.24-3.16), 2 serious outcomes per year between 2012 and 2017 (SD 1.3, 95% CI 1.06-3.34), and 10 serious outcomes per year between 2018 and 1019 (SD 2.83, 95% CI 6.07-13.92) (**Figure 3**).

Most children referred to a healthcare facility for management (2779 patients) were younger than 5 years of age (1524 patients, 54.8%) (**Table I**), although children in the older age groups were more likely to be admitted to the hospital (**Table III**; available at www.jpeds.com). A total of 91 children (6.0%) younger than 5 years of age had a medical effect from exposure as compared with 80 children (8.3%) between 6 and 12 years and 18 children (6.8%) between 13 and 19 years (**Table III**).

There was also a significant decrease in monthly magnet exposures during the traditional non-school months of June, July, and August compared with the traditional school months for the 13- to 19-year age group (5.6 per month vs 9.3 per month, $P < .05$) (**Figure 4**; available at www.jpeds.com). This seasonal decrease was not observed in the younger age groups.

Table I. Characteristics and outcomes of magnet exposure cases called into US poison control centers among children 0-19 years of age, 2008-2019

Characteristics	0-5 y, n (%)	6-12 y, n (%)	13-19 y, n (%)	Total cases, n (%)
Total patients	3572 (62.3%)	1738 (30.3%)	428 (7.5%)	5738 (100%)
Sex				
Male	1934 (54.1%)	1024 (58.9%)	211 (49.3%)	3169 (55.2%)
Female	1627 (45.5%)	699 (40.2%)	217 (50.7%)	2543 (44.3%)
Unknown	11 (0.3%)	15 (0.9%)	0	26 (0.5%)
Management site*				
Hospital	1524 (42.7%)	985 (56.7%)	270 (63.1%)	2779 (48.4%)
Onsite (non-HCF)	1983 (55.5%)	687 (39.5%)	123 (28.7%)	2793 (48.7%)
Other	29 (0.8%)	50 (2.9%)	28 (6.5%)	107 (1.9%)
Unknown	36 (1.0%)	16 (0.9%)	7 (1.6%)	59 (1.0%)
Medical outcome†				
No effect	966 (27.0%)	654 (37.6%)	129 (30.1%)	1749 (30.4%)
Minor	96 (2.7%)	72 (4.1%)	14 (3.3%)	182 (3.2%)
Moderate	13 (0.4%)	16 (0.9%)	5 (1.2%)	34 (0.6%)
Major	3 (0.1%)	2 (0.1%)	1 (0.2%)	6 (0.1%)
Confirmed nonexposure	347 (9.7%)	15 (0.9%)	4 (0.9%)	366 (6.4%)
Not followed	1738 (48.7%)	706 (40.6%)	175 (40.9%)	2619 (45.6%)
Unable to follow	379 (10.6%)	262 (15.1%)	96 (22.4%)	737 (12.8%)
Unrelated effect	30 (0.8%)	11 (0.6%)	4 (0.9%)	45 (0.8%)
Reason for ingestion				
Intentional	22 (0.6%)	612 (35.2%)	243 (56.8%)	877 (15.3%)
Unintentional	3547 (99.3%)	1105 (63.6%)	176 (41.1%)	4828 (84.1%)
Other/unknown	3 (0.1%)	21 (1.2%)	9 (2.1%)	33 (0.6%)

HCF, healthcare facility.
*Management site: coded based on where treatment was provided. Onsite = managed at home or non-HCF; unknown = includes cases that were lost to follow-up.
†Medical outcome: Coded based on symptoms the patient experienced. No effect = no symptoms; minor effect = quickly-resolving, minimally bothersome symptoms; moderate effect = non–life-threatening that were more pronounced, prolonged, or systemic (eg, injury without perforation); major effect = life-threatening or resulted in significant disability or disfigurement (eg, perforation); confirmed nonexposure = no radio-opaque object visualized on radiograph; not followed = poison centers did not perform follow-up, as it was deemed a nontoxic or minimal effect exposure; unable to follow = lost to follow-up and the exposure was significant and may have resulted in toxic manifestations; unrelated effect = the exposure was probably not responsible for the effect(s).

Table II. Analysis of study time periods including annual means and means comparisons

Age groups	Annual mean (95% CI) and median number of cases 2008-2011*	2012-2017†	2018-2019‡	Percent change 2008-2011 and 2012-2017	Comparison means 2008-2011 and 2012-2017	Percent change 2008-2011 and 2018-2019	Comparison means 2008-2011 and 2018-2019	Percent change 2012-2017 and 2018-2019	Comparison means 2012-2017 and 2018-2019
0-5 y	236 (182.9-288.3), 229	190 (167.7-211.9), 185	804 (425.4-1183.4), 804	−19%	NS	+302%	$P < .05$	+423%	$P < .05$
6-12 y	138 (101.7-175.1), 136	71 (55.9-85.3), 68	384 (130.9-635.9), 384	−49%	$P < .05$	+278%	$P < .05$	+540%	$P < .05$
13-19 y	43 (15.9-70.5), 41	21 (12.2-29.0), 19	60 (43.4-77.2), 60	−51%	NS	+14%	NS	+286%	$P < .05$
Total cases	418 (361.7-474.6), 406	281 (241.4-320.6), 264	1249 (573.8-1923.2), 1249	−33%	$P < .05$	+298%	$P < .05$	+444%	$P < .05$
Cases evaluated in hospital	212 (157.7-266.2), 192	151 (121.2-181.6), 132	537 (233.3-842.5), 537	−29%	NS	+254%	$P < .05$	+355%	$P < .05$

NS, no significant difference.
*2008-2011 = pre-CPSC action.
†2012-2017 = CPSC rule set in effect.
‡2018-2019 = post-CPSC rule set overturned.

Discussion

The data demonstrate a statistically significant change in cases of magnet exposure that correlates to magnet availability. In 2012, the US CPSC halted the sale of high-powered magnet sets and instituted a recall. In 2014, the CPSC finalized a federal rule (16 CFR Part 1240) limiting the strength and/or size of magnets sold as part of a set.[24] These actions effectively eliminated the sale of high-powered magnets from the market. Following the removal of high-powered magnet sets by the CPSC in 2012, cases decreased 33% until 2018 (Table II). This is consistent with other pre- and post-ban analyses and provides additional evidence that CPSC actions were successful in preventing many magnet-related childhood injuries.[21,25,28]

However, the CPSC rule set was overturned by the US Court of Appeals for the Tenth Circuit in December of 2016.[27] In a separate legal case, the recall order was ultimately overturned by the Federal District Court for the District of Colorado in June of 2018.[26] The result of these court decisions is that high-powered magnet sets can now be marketed and sold in the US to anyone 14 years of age and older. Our data demonstrate a 444% increase in magnet-related calls to PCCs since 2018 (Table II). This includes significant increases across all age groups when compared with years that these magnets could not be sold (2012-2017). Recent cases (2018 to 2019) have also increased ~300% compared with the time period before magnet sets were regulated (between 2008 and 2011).

Overall, roughly 7% of magnet exposures occurred in those 13-19 years of age—an age group that typically represents about 3% of pediatric foreign body exposures.[1] These risk patterns may be due to the unique ways in which high-powered magnets are used by teens, such as mimicking

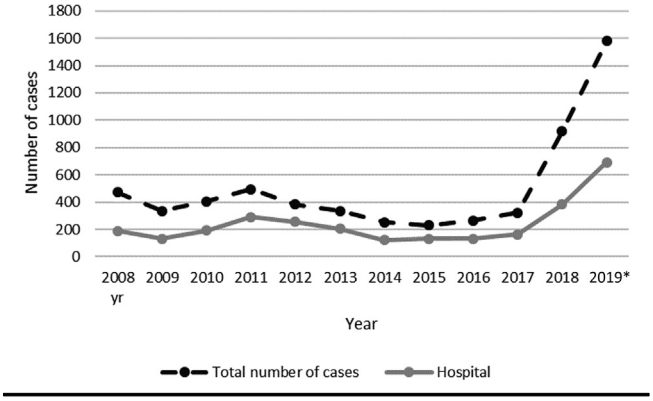

Figure 1. Total number of magnet exposure cases called into a US PCC and the number of cases referred to a hospital per year, 2008-2019. *Total exposures in 2019 were estimated proportionally using data up to October 31 (no. cases/304 days × 365 days = estimated no. cases).

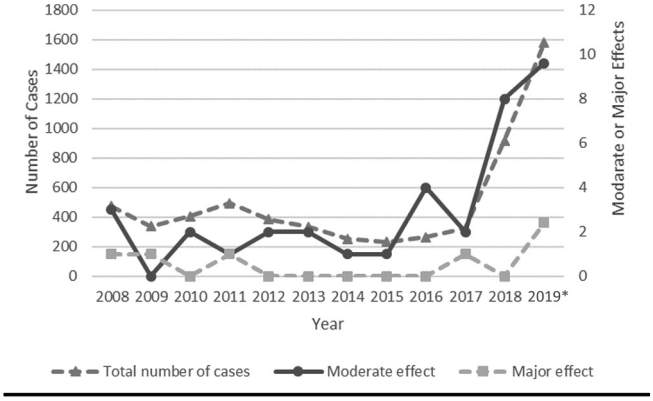

Figure 3. Number of cases per year with a major or moderate effect from a magnet exposure, 2008-2019. *Total exposures in 2019 were estimated proportionally using data up to October 31 (no. cases/304 days × 365 days = estimated no. cases).

tongue or lip piercings, or how products are shared between teens.

As shown in **Figure 4**, seasonality was also significantly associated with the number of PCC calls in teens. Magnet exposure calls decreased over the summer (June to August). The seasonality pattern of magnet exposure is consistent with the reported importance of school as a location of injury.[28] This suggests that peer interaction is a strong risk factor for exposure. Conversely, these data suggest that parental supervision may not substantially mitigate risk in teens.

Furthermore, patients with magnet exposure were roughly 8 times more likely to require hospital management compared with other foreign body exposures reported in the NPDS.[1] The percentage of patients referred for care within a hospital setting is consistent with the inherent risks of high-powered magnet ingestion but the admission rate of 7.0% (194 admissions per 2779 evaluations) greatly differs from previous reports of >70%.[12,22,23] This likely reflects sample bias within the data source. National Poison Centers are a voluntary resource to aid families and medical providers with poison exposures; the NPDS is not, therefore, a comprehensive registry. In addition, medical providers may not consider calling the Poison Help Line when treating magnet ingestions, especially if the patient presentation is delayed until the child is symptomatic or acutely ill. Research supports a significant decline in routine use of the poison center by emergency physicians since the increased availability of electronic resources such as PoisIndex.[33,34] Lastly, poison center contact is less likely when providers are faced with familiar exposures or those that may not be considered a "poison."[35] These cumulative facts seem likely to skew the cohort toward patients with less severe effects.

Reporting bias also may explain the small number (3.9%) of patients with minor, moderate, or major outcomes. Previous data have shown that 52% of patients with magnet ingestion require endoscopic interventions, 28% require surgery, and 34% have perforations and necrosis.[12,36] One single-center study found that 56% of patients with multiple magnet ingestion required endoscopy, surgery, or both; another showed that 75% required endoscopic or surgical intervention, with 50% having signs of peritonitis at the time of presentation.[23,37] Others have documented that ~17% of multiple magnet ingestions required partial excision of bowel and almost 5% needed multiple surgeries.[12] The NPDS classifications of outcomes does not include endoscopic or surgical procedures as an outcome. Therefore, patients who received successful endoscopic or surgical removal of magnets without findings of tissue injury are classified as having "no effect."

Strengths of this study include the relatively large sample size and features inherent to NPDS data, such as data entry by skilled professionals and highly protocolized processes. Limitations include the aforementioned voluntary nature of poison centers and a reporting bias toward less-ill children. This sample also does not distinguish between cases with single and multiple magnets, which may further bias results to less severe outcomes. In addition, NPDS data, as with other national databases, does not explicitly list specific magnet type. Future investigation confirming these findings and separating risk by magnet type is important. Lastly, 737 patients (12.8%) were classified as "unable to follow." The lack of outcome data for these patients is likely another reason for the lower-than-expected admission and "effect" data, as stated previously. These data reflect the urgent need to protect children via preventative efforts and government action. ■

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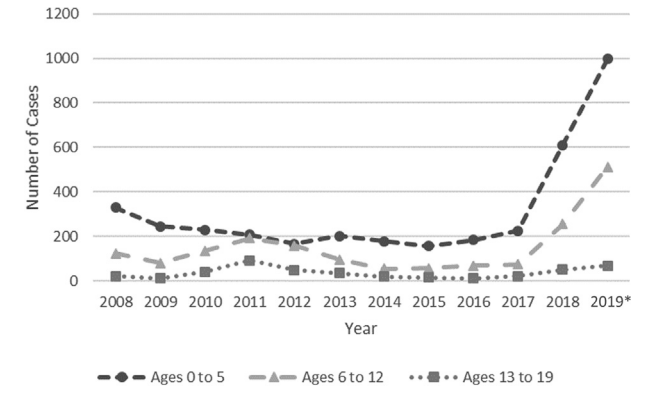

Figure 2. Number of magnet exposure cases by age group per year, 2008-2019. *Total exposures in 2019 were estimated proportionally using data up to October 31 (no. cases/ 304 days × 365 days = estimated no. cases).

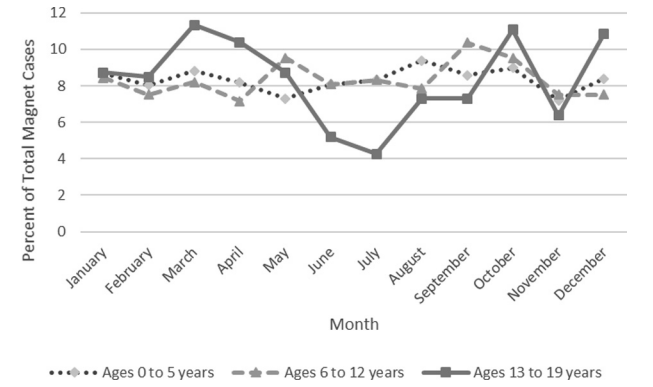

Figure 4. Percent of total magnet exposure cases per month, by age group.

Table III. Disposition and medical outcomes for patients managed in an HCF for a magnet exposure

Dispositions/outcomes	0-5 y, n (%)	6-12 y, n (%)	13-19 y, n (%)	Total cases, n (%)
Disposition*				
Treated and released	955 (62.7%)	565 (57.4%)	131 (48.5%)	1651 (59.4%)
Admitted to critical care	5 (0.3%)	12 (1.2%)	3 (1.1%)	20 (0.7%)
Admitted to noncritical care	49 (3.2%)	104 (10.5%)	21 (7.8%)	174 (6.3%)
Lost to follow-up/left AMA	375 (24.6%)	221 (22.4%)	91 (33.7%)	687 (24.7%)
Refused referral to HCF	137 (9.0%)	83 (8.4%)	24 (8.9%)	244 (8.8%)
Total	1524	985	270	2779
Medical outcome†				
No effect	557 (36.6%)	442 (45.7%)	96 (35.8%)	1095 (39.4%)
Minor	75 (4.9%)	62 (6.4%)	12 (4.5%)	149 (5.4%)
Moderate	13 (0.9%)	16 (1.7%)	5 (1.9%)	34 (1.2%)
Major	3 (0.2%)	2 (0.2%)	1 (0.4%)	6 (0.2%)
Confirmed nonexposure	234 (15.4%)	14 (1.5%)	4 (1.5%)	252 (9.1%)
Not followed	309 (20.3%)	199 (20.6%)	58 (21.6%)	566 (20.4%)
Unable to follow	312 (20.5%)	224 (23.1%)	88 (32.8%)	624 (22.5%)
Unrelated effect	21 (1.4%)	9 (0.9%)	4 (1.5%)	34 (1.2%)
Total	1524	985	270	2779

AMA, against medical advice; *HCF*, healthcare facility.
*Disposition: coded based on the highest level of care received. Treated and released = evaluated and discharged from a NCF (eg, emergency department); critical care = admitted to a critical or intensive care unit; noncritical care = admitted to a unit other than critical care; refused referral to HCF = patient declined referral or did not arrive at the HCF to which the patient was referred.
†Medical outcome: refer to **Table I** legend.