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2020 web**POISON**CONTROL data summary

Nicole E. Reid, BSN, EdM [a,b], Kelly Johnson-Arbor, MD [a,c,d], Susan Smolinske, PharmD [a,e,f], Toby Litovitz, MD [a,b,d,*]

[a] National Capital Poison Center, Washington, DC, United States of America
[b] The George Washington University School of Medicine, Washington, DC, United States of America
[c] MedStar Georgetown University Hospital, Washington, DC, United States of America
[d] Georgetown University School of Medicine, Washington, DC, United States of America
[e] College of Pharmacy, University of New Mexico, Albuquerque, NM, United States of America
[f] New Mexico Poison and Drug Information Center, University of New Mexico, Albuquerque, NM, United States of America

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ABSTRACT

Introduction: Increasing use of the internet for health information has decreased utilization of traditional telephone-based poison centers in the United States. web**POISON**CONTROL®, a browser-based tool and app was launched to meet the growing demand for online, personalized recommendations for human poison exposures. This study was conducted to characterize web**POISON**CONTROL cases and highlight its potential for real-time monitoring of poisoning.
Methods: Case data for all completed, nonduplicated public cases entered in 2020 were analyzed using a custom Qlik Sense dashboard.
Results: Of the 156,202 cases, 52.9% occurred in children younger than 4 years. Most cases (109,057, 69.8%) were initially triaged to home, 28.4% were advised to call Poison Control, and 1.7% were referred to the ED. Follow-up was available for 33.3% of home-triaged cases; 1.7% of those had a change in triage recommendation.
Pharmaceuticals were implicated in 41.5% of cases (nonpharmaceuticals in 58.5%). Ingestion was the most common route (88.4%, 138,012). One-time double dose therapeutic error cases were implicated in 17,901 cases (27.6% of pharmaceutical cases). Cosmetics (13.9%) and cleaning substances (12.9%) were the most frequent substance categories. Melatonin was the most frequently implicated generic substance (4.5% of cases). Most (72.0%) cases had no effect (21.4%), a minor effect (3.9%) or were minimally toxic with unknown outcome (46.7%). There were no deaths, 17 major outcomes (0.01%), and 26.7% of cases had potentially toxic exposures with no outcome determination.
In 2020, web**POISON**CONTROL handled 7.3% as many human poison exposure cases as were reported to U.S. phone-based poison centers. Online cases are skewed towards younger ages (53% in children younger than 4 years vs 37% of phone-based cases) and towards nonpharmaceuticals (58.5% vs 43.5%). Near real-time data visualizations enabled detection of COVID-19-related increases in exposures to hand sanitizers and cleaners, illustrating the public health surveillance and hazard detection capabilities of web**POISON**CONTROL.
Conclusion: The web**POISON**CONTROL tool provides a safe, quick and fully-automated alternative to those who are unable or unwilling to use the telephone to call a traditional poison center.

1. Introduction

The first poison control centers in the United States, established in the 1950's, were initially developed to provide information to healthcare professionals on toxic ingredients in household products [1,2]. As of 2021, 55 U.S. poison control centers are accessible through a single toll-free number (1–800–222-1222) and provide telephone-based advice to healthcare professionals and the public for the diagnosis and clinical management of more than 2 million potentially toxic human poison exposures annually [3]. Although they operate independently, all 55 centers are staffed by specially trained healthcare providers and collect and submit case data to the National Poison Data System (NPDS) [3].

The advent of the public internet in the 1990's transformed methods of information acquisition and delivery worldwide, including within the healthcare industry. The internet contains a vast repository of health-related information ranging from personal blogs to peer-reviewed

* Corresponding author at: National Capital Poison Center, Washington, DC, United States of America.
E-mail address: toby@poison.org (T. Litovitz).

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literature, and many individuals rely on this as a primary source of medical knowledge [4]. Health information seeking is a function of both need and access; the internet provides easy access when individuals have an actual or perceived need to acquire health-related knowledge [5]. From a poison control perspective, this shift in information-gathering methods created a need for an easy-to-use, accurate, evidence-based online toxicology resource for the public that could mimic the experience of calling poison control.

The web**POISON**CONTROL® app and browser-based tool were released in December 2014 to meet a growing public demand for internet-based, case-specific poison control services [6]. Users access web**POISON**CONTROL either as a browser-based tool (accessed at www.poison.org) or as a mobile app downloaded from either the App Store or Google Play. Most users find the tool when seeking assistance for a poison exposure online through a web search engine. Results of a pilot version of web**POISON**CONTROL, reported in 2016, demonstrated safety and ease of use in 9256 consecutive cases logged from Feb 11, 2015 to Feb 25, 2016 and provided details on the original scope of the tool [6]. Ongoing survey feedback from nearly 20,000 users has contributed to continuing improvements to the user experience and expanded scope (Table 1).

web**POISON**CONTROL users receive a case-specific, personalized recommendation for a poison exposure. They begin by entering age, sex, reason, substance, route, amount (single exposure, double-dosing or dosing too close), presence or absence of symptoms (and if symptomatic, whether all symptoms are expected and not severe), and time elapsed since the poison exposure. Substances can be entered by searching for the substance name, entering the pill imprint, or by scanning or typing the product UPC (barcode). Each substance ingredient is matched to an algorithm that defines referral thresholds in a number of ways. For ingestions and bites and stings, the thresholds utilize age, weight, amount (or number of bites), symptoms and time since exposure. Referral strategies for eye, skin, inhalation and injection exposures are based on a combination of toxicity and severity expected for the ingredient and route, and a symptom assessment. Evidence-based algorithms are written by poison experts and peer reviewed by a team of clinical and medical toxicologists. Participating poison centers (24 in 2020) also play a critical role in continued algorithm refinement, both proposing and approving changes. web**POISON**CONTROL does not attempt to triage or provide guidance for cases of intended self-harm, extremes of age (< 6 months or > 79 years), pregnant patients, patients with underlying serious illness, exposures to multiple substances, or chronic exposures other than one-time double-dose therapeutic errors. Instead, all of these individuals are given immediate instructions (and dialing links) to call Poison Control. Since these excluded entries cannot complete the app, they are not included in the analysis which follows.

After answering questions about the exposure, the user is provided with one of three recommendations:

1) *Stay home*. It is safe for the exposed person to stay home because significant toxicity is minimal.
2) *Go to the Emergency Department (ED)*. Significant toxicity is likely therefore an ED evaluation is required. Specific criteria for calling 911 are provided.
3) *Call Poison Control*. Significant toxicity is possible so a call to Poison Control is warranted in order to obtain more information to evaluate the case, to provide guided monitoring, or to confirm that ED evaluation is necessary.

Cases triaged to home management receive specific instructions on common expected symptoms (including a timeline for onset and duration), clinical effects that should prompt a call to poison control, and those manifestations which should trigger an immediate ED evaluation. Automated follow-up is conducted in a separate interface which is reached by clicking on the emailed recommendation or through timed reminder emails. Follow-up enables tracking of user actions, symptoms that developed and their severity, and a possible change in triage recommendation based on those symptoms.

The user may opt to receive automated follow-up reminders and a copy of the detailed recommendations by email. During automated follow-up, the user identifies specific symptoms that developed, if any, designates the severity and persistence of each symptom, and indicates what was actually done (stayed home, went to ED, etc). The symptoms are compared to known worrisome effects of the product or substance, triggering a change in the triage recommendation if indicated. Follow-up reminders are sent at pharmacokinetically appropriate intervals.

This analysis focuses on the 156,202 nonduplicated cases handled by web**POISON**CONTROL in 2020, providing insight into the types of cases managed by the application, characterizing the data, and highlighting its potential use as an additional resource for real-time monitoring of poisoning in the United States.

Table 1
Timeline of web**POISON**CONTROL enhancements.

Enhancement	Implemented
Initial version covering single acute ingestions in asymptomatic individuals	12/30/2014
Enabled user-designation of test ("fake") cases so these could be eliminated from analyses	2/11/2015
Enabled email opt out	3/16/2015
Launched new poison.org website	9/4/2015
Improved substance search	10/8/2015
Reordered presentation of questions	5/12/2016
Added handling of symptomatic ingestions	6/9/2017
Added eye, skin, inhalation, injection routes	8/14/2017
Added bite/sting route	12/4/2017
Enabled new UPC (Universal Product Code or barcode) database format and provider	8/20/2018
Enabled back end for double-dose therapeutic errors	12/3/2018
Added user-entry of double dose therapeutic errors	5/3/2019
Enabled substance entry by barcode scanning from mobile browser (previously only in app)	9/19/2019
Launched business intelligence dashboard	5/4/2020
Expanded PC/ER designation by specific symptom to include ingestion route	8/13/2020
2343 algorithms; 129,172 fully-matched substances; 1,070,074 attached UPCs	12/31/2021

2. Methods

web**POISON**CONTROL variable definitions are nearly identical to those of the National Poison Data System (NPDS), a national database of information collected by traditional poison centers in the U.S. (see definitions, [3]). Collected case data include age, sex, weight, specific product and generic substances, amount, clinical effects, outcome, double-dose therapeutic errors, time since exposure (not included in NPDS), and geolocation (which determines the assigned poison center should further guidance be required). Outcome coding options (no effect, minor effect, major effect, death, unknown potentially toxic and confirmed nonexposure) have definitions identical to those used in NPDS [3]; however, the two "unknown nontoxic" and "unknown minimally toxic" outcome values used in NPDS are lumped together as "unknown minimally toxic" in web**POISON**CONTROL. A hierarchical categorization scheme for substances mirrors that used in NPDS, categorizing specific products to generic substances (called "generic codes" in NPDS), and each of those generic substances to generic subcategories or categories [3]. Cases with changes in the triage recommendation are captured by comparing "final triage" with "initial triage".

Toxicologists and Certified Specialists in Poison Information audit 30% of the prior day's cases daily. A computer-assisted duplicate detection method is used to identify, mark and exclude likely duplicates from further data analyses. Auditors meticulously review and recalculate ingested amounts compared to thresholds for each ingredient. Cases with severe outcomes and their associated algorithms are further reviewed. Audit timing switches from next-day auditing to near real-time auditing for the 7–10 days following each software upgrade.

All cases (156,202) were entered by public users during 2020. Unless otherwise specified, the term "case" refers to a complete, nonduplicated, non-test entry by a public user. A case does not include an entry marked by the user as a confirmed nonexposure. The following data entries were excluded from this analysis:

1) Incomplete entries (478,079), including entries where the user clicked into the tool from a search engine result but answered no questions (356,838 entries; 74.6% of all incomplete entries), entries where the user decided to abandon the tool after answering some questions (67,315), and entries where the tool directed the user to call poison control prior to case completion due to an incompatible circumstance (53,926);
2) Duplicate entries (16,523);
3) Entries initiated by poison centers using the "Calculate it for Me" tool to assist with telephone case management. This non-public facing tool is a modification of web**POISON**CONTROL developed to assist poison control center staff with telephone-based cases;
4) Entries marked as test or demo cases by users (103,754 users checked "I'm just trying the tool. This is not a real case."); and
5) Confirmed nonexposures: 2175 completed non-test, non-duplicate entries where the user indicated on follow-up that "nothing was swallowed".

Data analyses, hazard detection, and case monitoring for frequency or severity spikes are available in near-real time and conducted using a customized Qlik Sense® dashboard. That dashboard was used for this analysis and characterization of 2020 non-duplicated, non-test cases entered by public users (not by poison control center Specialists in Poison Information). For additional information, see the publicly-accessible web**POISON**CONTROL Data Analysis Dashboard released in January 2022 or the accompanying description of the data.

Expected versus observed distributions of categorical data were compared using the chi-square test for independence. *P*-values of <0.05 were considered statistically significant.

This study was deemed exempt from review by The George Washington University Institutional Review Board.

3. Results

Over 625,000 cases have been managed by web**POISON**CONTROL since 2015 (through 2021; Table 2). In 2020, 156,202 entries qualified as cases and are the focus of this analysis. Of these, 142,798 (91.4%) were from the U.S. and 13,402 (8.6%) were international. State utilization rates varied 2.7-fold, from 31.0 to 82.5 cases/100,000 population (utilization rate for U.S. excluding territories: 43.3 cases/100,000), with the highest utilization rates seen (in descending order) in Utah, Alaska, Wyoming, Idaho, North Dakota, West Virginia, Colorado, Maine, Montana, Kansas, Oregon and Oklahoma. The average daily case count was 427 (range 305 to 650 cases), with SARS-CoV-2 (COVID-19)-related increases observed from mid-March to late April 2020.

Table 2
Case count by year.

Year*	Nonduplicated, non-test cases (excluding confirmed nonexposures)	Cumulative case count
2015	6,011	6,011
2016	26,847	32,858
2017	42,155	75,013
2018	113,527	188,540
2019	160,704	349,244
2020	156,202	505,446
Total	505,446	505,446

* 314 cases from 12/30/2014 (launch) to 2/10/2015 excluded as user did not have an option to identify test cases.

3.1. Age & sex

Most cases occurred in children, with 52.9% of cases occurring in children younger than 4 years, 22.4% in 1 year olds and 16.2% in 2 year olds (Fig. 1). Children and adolescents, through 19 years of age, comprised 69.1% of cases. Overall, 53.6% of cases occurred in females, with females outnumbering males in all age groups over 12 years (Fig. 2).

3.2. Triage recommendations, follow-up, substances, symptoms & outcome

Most cases (109,057, 69.8%) were initially triaged to home with instructions on symptoms to watch for that should trigger a change in triage (call to Poison Control or ED visit) and with automated follow-up available through the web**POISON**CONTROL follow-up module. Initial triage to Poison Control occurred in 44,439 cases (28.4%) and to the ED in 2706 cases (1.7%).

Of the 109,057 cases initially triaged to home, 70.8% (77,183) provided email addresses enabling automated notifications at appropriate follow-up times (note that all confirmed nonexposures also completed follow-up but were excluded from this analysis). Of all users initially triaged to home, 36,341 (33.3%) logged into the follow-up module and completed at least one (and up to 9) follow-ups (mean 1.72). Of all users initially triaged to home with follow-up and with no subsequent change in the web**POISON**CONTROL triage recommendation (n = 35,729), only 161 (0.45%) indicated they eventually went to an ED. Outcomes of cases initially triaged to home with follow-up (n = 36,341), included no effect in 81.8% (n = 29,730), minor outcome in 14.1% (n = 5122), moderate outcome in 3.2% (n = 1179), major outcome in 0.02% (n = 6), unknown minimally toxic in 0.8% (n = 303), unknown potentially toxic in 0.0% (n = 1), and no deaths.

A change in the initial home-triage recommendation occurred during follow-up in 612 cases. This represented 1.7% of home triaged cases with follow-up; 465 were later referred to Poison Control and 147 to the ED. Cases with a change in triage involved ingestion alone (as the only route) (61.1%, compared to 85.7% of home triage cases with follow-up but without a change in triage), inhalation alone (12.1%, compared to 2.2% of those without a change in triage), eye alone (8.0%, compared to 2.8%), and bites/stings (5.6%, compared to 0.6%). Thus, routes with triage determined by symptoms more than by quantitative amount thresholds contributed more heavily to triage changes. The most common symptoms reported on follow-up that led to a change in triage were nausea (14.5%), drowsiness (14.4%), headache (13.1%), abdominal pain (11.8%), dyspnea (11.3%), dizziness (11.1%), vomiting (10.3%), diarrhea (9.2%), cough (8.2%), and ocular irritation (8.0%); some patients reported multiple clinical effects. Among cases initially triaged to home with follow-up, the triage recommendation was eventually changed 10.5 times more often in cases that reported initial (expected) symptoms (8.0%; 372 of 4653 cases) compared to cases that were initially asymptomatic (0.76%; 240 of 31,685 cases, $P < .00001$, chi-square).

Pharmaceuticals were implicated in 41.5% of cases (64,781 cases) and nonpharmaceuticals in 58.5% (91,421 cases). Pharmaceuticals were more often triaged to home than nonpharmaceuticals (73.2% compared to 66.7%, final triage, $P < .00001$, chi-square). Pharmaceuticals were less often triaged to poison control (24.1% of pharmaceutical cases compared to 31.9% of nonpharmaceuticals, $P < .00001$, chi-square), but pharmaceutical cases were more often triaged to the ED (2.6% of pharmaceutical compared to 1.4% of nonpharmaceutical cases, $P < .00001$, chi-square).

Final triage to home was more common in children younger than 13 years compared to any other age group, and 75.5% of children younger than 6 years were triaged to home. While home triage was also the most common triage site for older age groups, it accounted for only

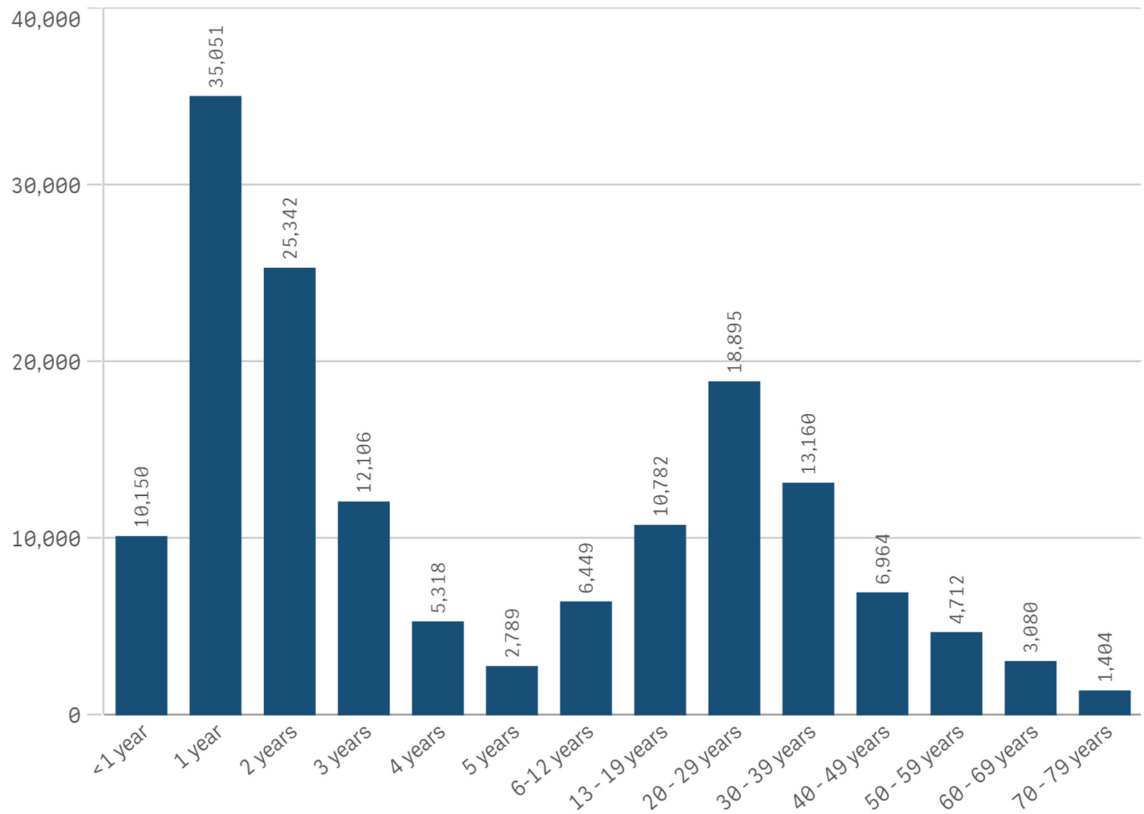

Fig. 1. Age distribution (case count by age).

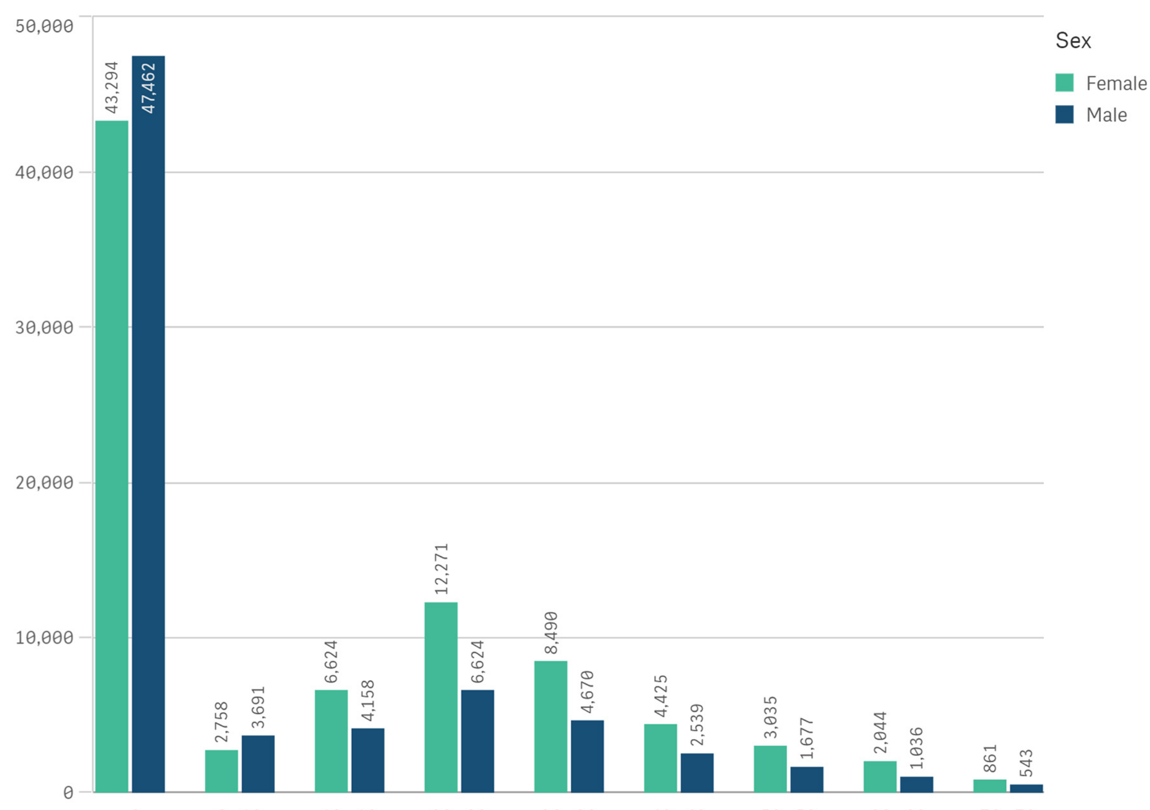

Fig. 2. Distribution (case count) by age (years) and sex.

54.8 to 63.9% of triage recommendations in each age group from 13 to 79 years. A corresponding increase in both recommendations to call poison control and in ED referrals was noted in these older age groups, with 5.2% of patients 60 years and older referred to the ED compared to 0.9% of children younger than 6 years. Likewise, poison control referral percentage was highest for teens (41.7%) compared to just 23.6% of children younger than 6 years.

The final triage recommendation by generic category is shown for nonpharmaceuticals (Fig. 3) and pharmaceuticals (Fig. 4). Cosmetics (13.9%), cleaning substances (12.9%), analgesics (6.6%), dietary supplements (6.0%) and topical preparations (4.7%) were the most frequently implicated substance categories, with these 5 categories comprising 44.1% of cases (Fig. 5, showing age distribution in each category). Eight nonpharmaceutical categories had more than 75% of cases triaged to home (final triage recommendation, including arts/crafts [94.1%], dyes [85.7%], polishes/waxes [83.0%], plants [79.5%], adhesives/glues [78.3%], matches/fireworks [78.1%], foreign bodies/toys [77.8%], and fertilizers [75.1%]), reflecting the lower toxicity of many products in these categories. Likewise, eight pharmaceutical categories had more than 75% of cases triaged to home (vitamins [86.9%], dietary supplements [86.9%], hormones/hormone antagonists [86.1%], veterinary drugs [85.9%], antimicrobials [80.9%], gastrointestinal preparations [77.1%], and ear/nose/throat preps [76.6%], and antihistamines [75.4%]. All exposure routes were included in this assessment of home triage frequency, but categories with fewer than 10 cases were excluded. In contrast, rates of final triage to the ED exceeded 5% for 7 categories, including batteries [92.8%], heavy metals [38.7%], cardiovascular drugs [14.0%], automotive products [13.3%], antineoplastics [9.6%], chemicals [7.0%], and building/construction products [5.9%]).

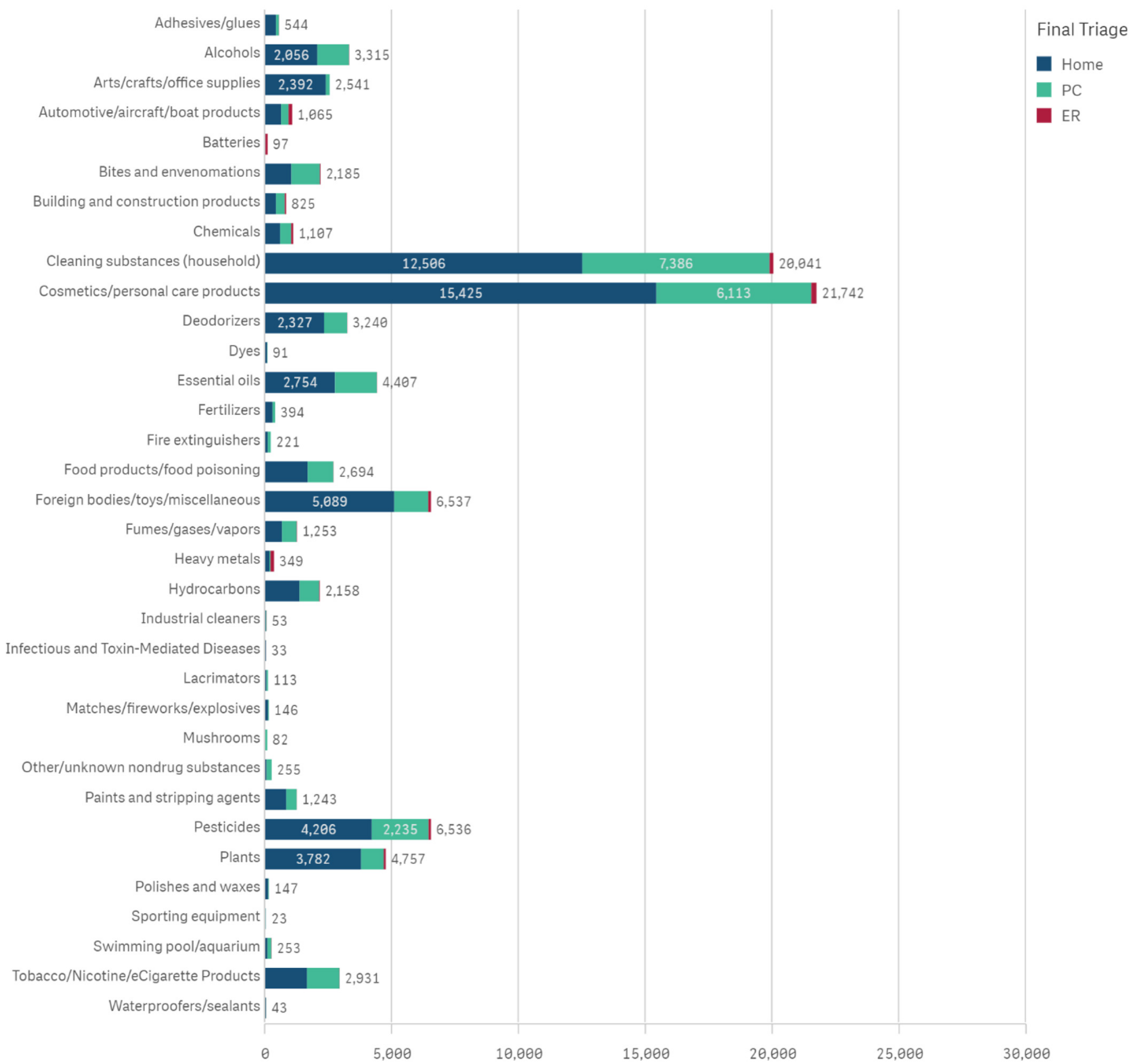

Fig. 3. Nonpharmaceuticals: Final triage by generic category.
(PC = Call Poison Control; ER = Emergency Department)

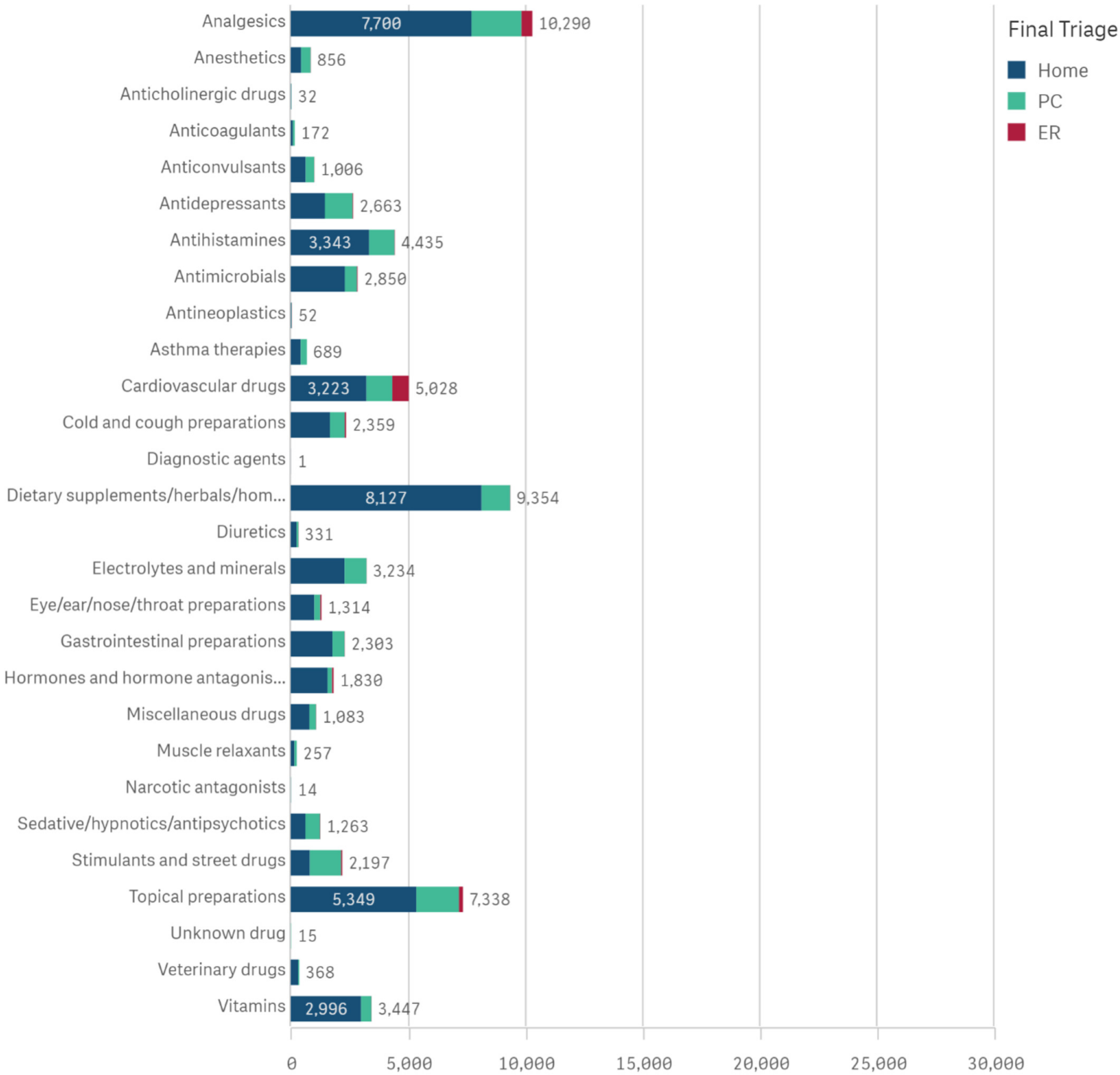

Fig. 4. Pharmaceuticals: Final triage by generic category.
(PC = Call Poison Control; ER = Emergency Department)

Substances implicated for infants and toddlers showed considerable age-specificity. Children 2 years and younger comprised 45.2% of all exposures, 49.2% of the 91,421 nonpharmaceutical exposures, and 39.4% of the 64,781 pharmaceutical exposures. For children 2 years and younger, nonpharmaceuticals comprised a higher percent of cases (63.8% of cases, compared to 54.2% of cases older than 2 years, $p < .00001$, chi-square). Table 3 shows the substance categories most frequently implicated in the youngest children, by year, for children younger than 3 years. In the three age groups shown, cosmetics and personal care products, followed by cleaners were the most frequently involved substance categories. Remarkably, of the 2931 cigarette and tobacco product exposures, 30.4% occurred in children younger than one year of age and another 46.3% occurred in one year olds. Two-year-old children were involved in 29.6% of the 3447 vitamin exposures.

The most frequently implicated substances by generic substance included melatonin (7044 cases, 4.5% of cases), ibuprofen (4003 cases, 2.6%), ethanol-based hand sanitizers (3349 cases, 2.1%), cream, lotion and make-up (2293, 1.47%), hypochlorite bleach (2173, 1.4%), toothpaste with fluoride (2117, 1.4%), other foreign body (2067, 1.3%), liquid air fresheners (2061, 1.3%), other essential oils (2048, 1.3%) and pyrethroids (2038, 1.3%). Of those, only hypochlorite bleach (2.0%) and pyrethroids (3.1%) had more than 1% of cases with serious (moderate or major) outcomes.

Most (72.0%) of web**POISON**CONTROL cases had no effect (21.4%), a minor effect (3.9%) or were minimally toxic exposures with unknown outcome (46.7%). There were no deaths, 17 major outcomes (0.01%), and 26.7% of cases had potentially toxic exposures with no outcome determination because they were referred to call Poison Control or go to

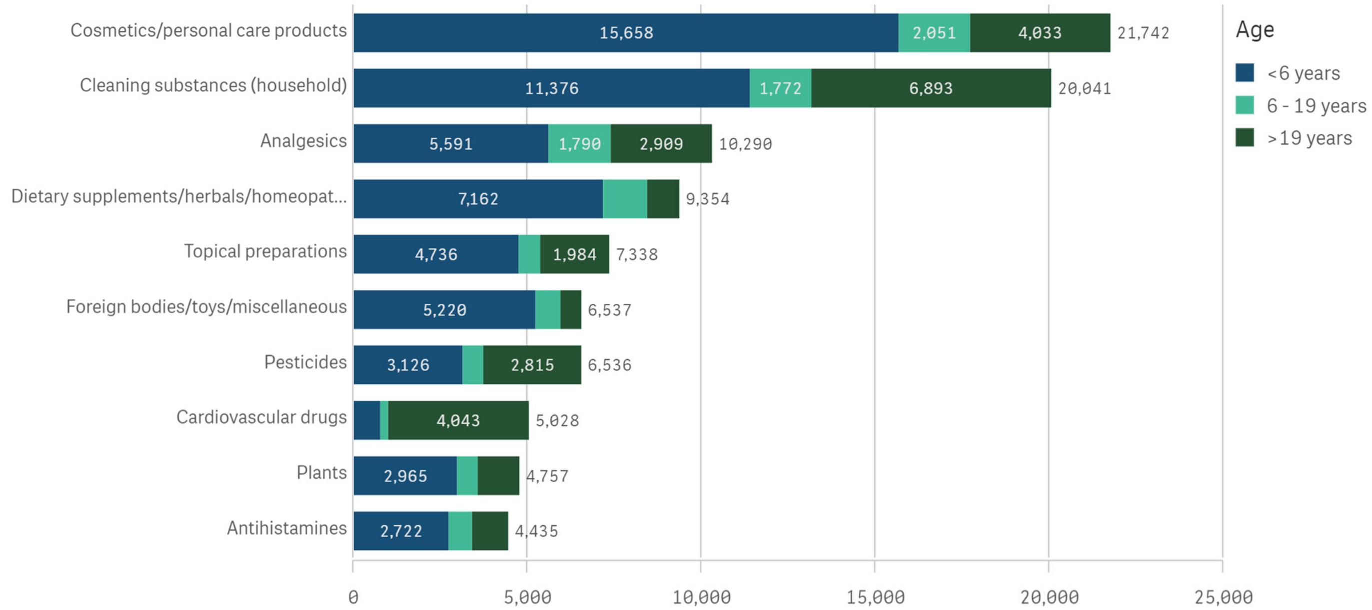

Fig. 5. Age distribution of most frequent substance categories.

an ED. Compared with other age groups, the rate of no effect and "unknown, minimally toxic" outcomes was higher in children younger than 12 years, and the rates of moderate and "unknown, potentially toxic" outcomes were lower in the youngest children (Table 4).

At the time the user completed the triage app and received an initial recommendation, 61.6% indicated the exposed individual had no symptoms, 10.0% noted expected symptoms (from a list of common and expected symptoms associated with the ingredients of the substance implicated), 9.6% described severe or unexpected symptoms, and 1.2% described symptoms present, but they were not characterized as common or severe/unexpected. In line with the effort to present the least number of questions required for safe triage, 17.6% of users were not asked about symptoms because the amount or inherent toxicity of ingredient(s) mandated a referral to an ED or call to Poison Control. On follow-up, users reported 11,532 specific symptoms which developed (some cases with more than one symptom), the most frequent of which were nausea (1129), vomiting (1037), lethargy (1023), abdominal pain (906), diarrhea (853), and headache (605).

Table 3
Top 5 substance categories in poison exposures in children younger than 3 years

Age		Count	% of cases in age group
<1 year	**All cases**	**10,150**	
	Cosmetics & personal care	1,673	16.5%
	Cleaners	1,248	12.3%
	Tobacco products	892	8.8%
	Foreign bodies & toys	858	8.5%
	Topical pharmaceuticals	717	7.1%
	Subtotal, top 5	5,388	53.1%
1 year	**All cases**	**35,051**	
	Cosmetics & personal care	7,032	20.1%
	Cleaners	5,417	15.5%
	Topical pharmaceuticals	2,166	6.2%
	Analgesics	1,945	5.5%
	Foreign bodies & toys	1,777	5.1%
	Subtotal, top 5	18,337	52.3%
2 years	**All cases**	**25,342**	
	Cosmetics & personal care	4,114	16.2%
	Cleaners	2,965	11.7%
	Dietary supplements & homeopathics	2,500	9.9%
	Analgesics	1,765	7.0%
	Topical pharmaceuticals	1,255	5.0%
	Subtotal, top 5	12,599	49.7%

3.3. Route of exposure, amount & formulation

Ingestion was the most common exposure route (88.4%, 138,012), occurring as the only route in 129,916 (83.2% of cases), and combined with other routes in 8096 (5.2% of cases). Inhalation alone (5549, 3.6%), eye alone (5011, 3.2%), ingestion and dermal (4799, 3.1%), dermal alone (4340, 2.8%), and bite/sting (1881, 1.2%) were the next most common routes.

Focusing on single-route exposures, the highest percentage of Poison Control referrals (final triage recommendation) occurred with injection cases (88.4% referred), followed by bites/stings (57.9%) referred, compared to just 26.1% of ingestions. For single-route exposures, ED referrals were highest for eye exposures (3.6%) compared to just 1.9% of ingestions and 0.8% of inhalation exposures.

The triage app was developed to ask the minimum number of questions required to accurately triage the user. Accordingly, the user is not asked the specific amount of exposure if all ingredients are matched to minimally toxic or symptom-based triage algorithms or a zero-threshold algorithm is present, implying the substance is sufficiently toxic that any amount should be triaged to an ED or to Poison Control. Of 138,012 cases with ingestion as the only or one of several routes, amount was not asked in 26.6% (36,740).

The formulation of the user-selected substance determines the sequence of questions and available responses. For example, formulation limits the exposure routes the user can select and the units of measure allowed for amount entries. The most common formulations were liquids (55,385), pills (43,011), creams and ointments (13,554), granules and powders (10,717), sprays (10,299), pieces (7560), packets (3586), bites/sting (1881), seeds (1860), cigarettes (1611, plus 238 cigarette butts), bars (1535), berries (1442), and gases (1383), among others. Formulations with the highest percentage triaged to home included swallowed insect/animal (97.9% of 47 cases), lozenges (86.9% of 390), berries (86.8%), cigarette butts (86.6% of 238), seeds (86.0%), and bars (85.4%). The highest ED referral (final triage) rates occurred with patches (12.5% of 56), pieces (4.9%), and pills (3.1%). The highest Poison Control final triage rates occurred with packets (63.6%), cigars (58.9% of 95), and bites/stings (57.9%). The formulations with the highest percentage of cases in children younger than 6 years were cigarettes (94.7%), cigarette butts (94.5%), bars (87.4%), berries (84.6%), and swallowed insects (83.0%). The formulations with the highest

Table 4
Age by outcome.

Age	Total cases		No Effect		Minor		Moderate		Major		Death		Unknown, minimally toxic		Unknown, potentially toxic	
	No.	col %	No.	row %	No.	row%	No.	row %	No.	row %	No.	row %	No.	row %	No.	row %
<6	90,756	58.1%	23,827	26.3%	2,433	2.7%	321	0.4%	1	0.0%	0	0.0%	44,763	49.3%	19,411	21.4%
6–12	6,449	4.1%	1,621	25.1%	305	4.7%	54	0.8%	0	0.0%	0	0.0%	3,049	47.3%	1,420	22.0%
13–19	10,782	6.9%	956	8.9%	433	4.0%	263	2.4%	6	0.1%	0	0.0%	4,719	43.8%	4,405	40.9%
20–29	18,895	12.1%	2,138	11.3%	982	5.2%	513	2.7%	3	0.0%	0	0.0%	8,587	45.4%	6,672	35.3%
30–39	13,160	8.4%	1,841	14.0%	811	6.2%	376	2.9%	4	0.0%	0	0.0%	5,587	42.5%	4,541	34.5%
40–49	6,964	4.5%	1,126	16.2%	490	7.0%	203	2.9%	1	0.0%	0	0.0%	2,778	39.9%	2,366	34.0%
50–59	4,712	3.0%	841	17.8%	347	7.4%	115	2.4%	2	0.0%	0	0.0%	1,839	39.0%	1,568	33.3%
60–69	3,080	2.0%	689	22.4%	229	7.4%	73	2.4%	0	0.0%	0	0.0%	1,156	37.5%	933	30.3%
70–79	1,404	0.9%	340	24.2%	93	6.6%	40	2.8%	0	0.0%	0	0.0%	539	38.4%	392	27.9%
Total	156,202	100.0%	33,379	21.4%	6,123	3.9%	1,958	1.3%	17	0.0%	0	0.0%	73,017	46.7%	41,708	26.7%

percentage of cases in adults from 20 to 59 years included gases (75.1%), bites/stings (66.8%), and patches (51.8%).

3.4. Double-dose therapeutic errors

One-time double dose therapeutic error cases were implicated in 17,901 cases (11.5% of all cases and 27.6% of the 64,781 pharmaceutical cases). In this subset, the age distribution showed a prominent peak in the 20- to 39-year-old demographic (Fig. 6). Females comprised 61.6% of double-dose cases and females were predominant in age groups over 12 years (Fig. 7). Cardiovascular drugs (21.2%) and analgesics (19.9%) were the pharmaceutical categories most often implicated in double-dose errors (Table 5). Double-dose therapeutic errors were implicated in at least 50% of cases in these pharmaceutical categories: cardiovascular drugs (75.4%), anticonvulsants (55.7%), diuretics (59.8%), and anticoagulants (50.0%). Double-dose cases were triaged to home in 71.8% of cases, to Poison Control in 24.1% and to the ED in 4.2% (final triage).

*3.5. Use of web**POISON**CONTROL for public health surveillance and hazard detection: COVID-19*

The web**POISON**CONTROL poison control analytics dashboard enables near real-time analysis by algorithm, substance, and generic

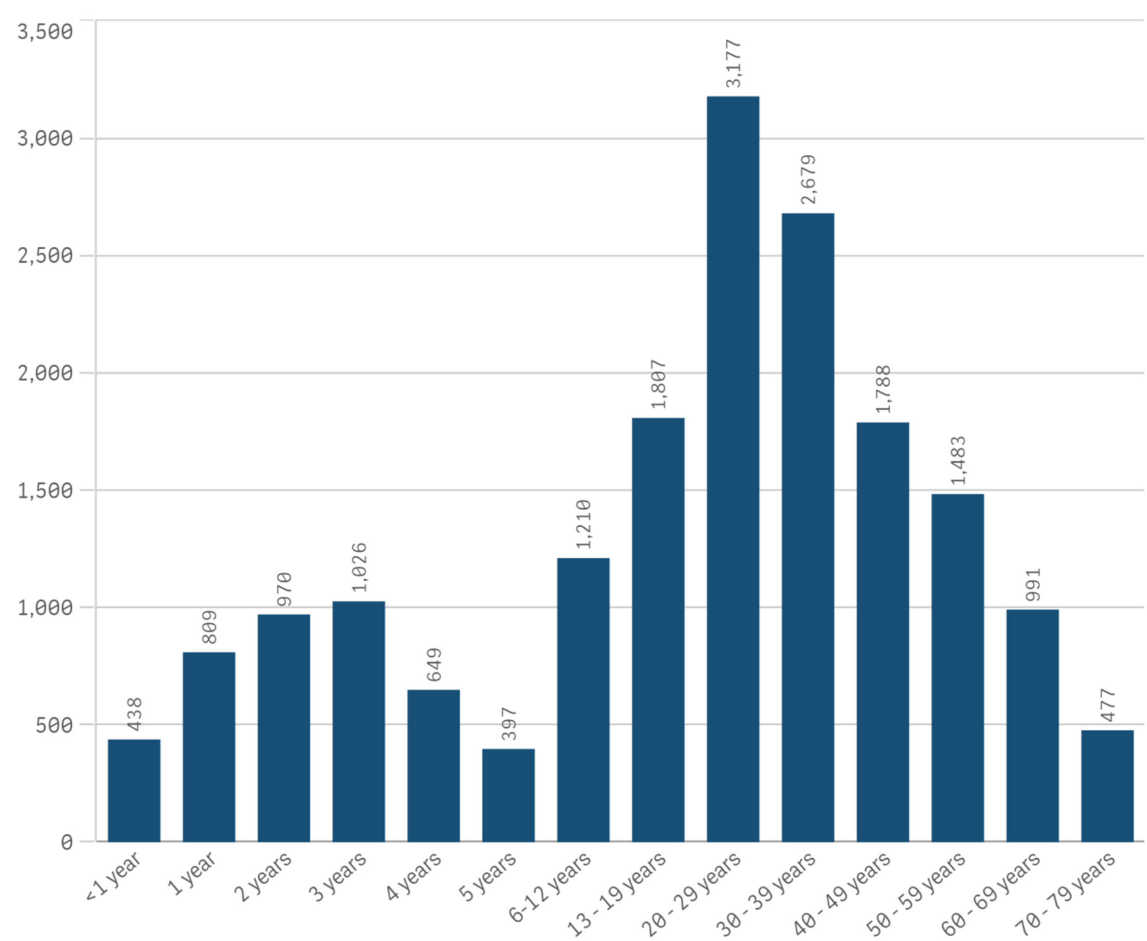

Fig. 6. Age distribution for double-dose therapeutic errors.

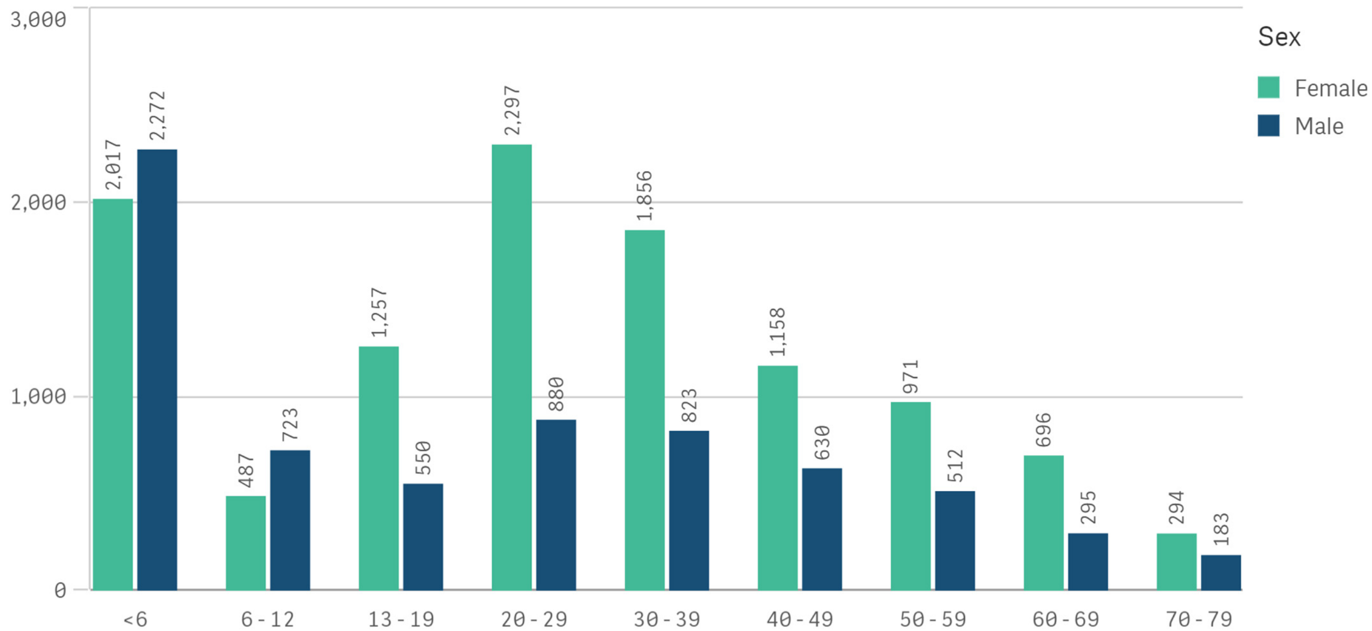

Fig. 7. Age (years) and sex distribution for double-dose therapeutic errors.

substance code, focusing on those with the highest rates of severe outcomes (moderate, major or fatal), and those with the most frequently changed triage recommendations. These analyses enable rapid identification of potentially problematic products or algorithms, serving both a quality assurance purpose for the web**POISON**CONTROL tool and a public health purpose for identification of unusual product hazards. Another component of the analytics dashboard provides data visualizations and mapping for the comparison of two time periods, searching for spikes in case counts, average cases/day or percent of cases, for each substance, generic category, algorithm, final triage, final outcome, state, country or geographically-assigned poison center.

In 2020, web**POISON**CONTROL showed a 51% increase in nonduplicated, completed public cases in March and April compared to the first 2 months of the year. The increase was associated with the COVID-19 outbreak and was attributed to simultaneous spikes in hand sanitizer, ethanol, household bleach, hydrogen peroxide,

Table 5
Double-dose therapeutic errors by generic substance category

	Count of all pharmaceutical cases	Count of double-dose cases	% of all double-dose cases	% of cases in category that involve a double dose
Analgesics	10,290	3,566	19.92	34.66
Anesthetics	856	0	0.00	0.00
Anticholinergic drugs	32	3	0.02	9.38
Anticoagulants	172	86	0.48	50.00
Anticonvulsants	1,006	560	3.13	55.67
Antidepressants	2,663	1,263	7.06	47.43
Antihistamines	4,435	1,697	9.48	38.26
Antimicrobials	2,850	960	5.36	33.68
Antineoplastics	52	17	0.09	32.69
Asthma therapies	689	213	1.19	30.91
Cardiovascular drugs	5,028	3,792	21.18	75.42
Cold and cough preparations	2,359	800	4.47	33.91
Diagnostic agents	1	0	0.00	0.00
Dietary supplements/herbals/homeopathic	9,354	1,768	9.88	18.90
Diuretics	331	198	1.11	59.82
Electrolytes and minerals	3,234	283	1.58	8.75
Eye/ear/nose/throat preparations	1,314	8	0.04	0.61
Gastrointestinal preparations	2,303	303	1.69	13.16
Hormones and hormone antagonists	1,830	397	2.22	21.69
Miscellaneous drugs	1,083	180	1.01	16.62
Muscle relaxants	257	84	0.47	32.68
Narcotic antagonists	14	4	0.02	28.57
Sedative/hypnotics/antipsychotics	1,263	492	2.75	38.95
Stimulants and street drugs	2,197	556	3.11	25.31
Topical preparations	7,338	19	0.11	0.26
Unknown drug	15	0	0.00	0.00
Veterinary drugs	368	0	0.00	0.00
Vitamins	3,447	650	3.63	18.86
Other		2	0.01	
Total	64,781	17,901	100.00	27.63

multi-purpose cleaners, hand dishwashing liquids, vitamins and melatonin cases. Based on feedback surveys from users, it is likely that a portion of that increase can be attributed to web**POISON**CONTROL serving as the surge capacity for phone-based poison centers that were handling an influx of COVID-19-related calls in additional to routine poison control services.

3.6. User experience, utilization, and app operation

The median time required for case completion (data entry to comprehensive recommendations) was 164 s (2.7 min), excluding cases with >10 min pauses (periods of inactivity) in case completion. Time from exposure to start of case entry in web**POISON**CONTROL was <10 min for 24.2% of cases with known time of exposure, <20 min for 49.8% of cases, <1 h for 67.0% of cases, and < 2 h for 77.8% of cases, and < 24 h for 94.1% of cases. Time of exposure was unknown in 3.0% of cases.

Substance entry method involved searching for the name in 94.7% (147,983) of cases, scanning the barcode in 3.3% (5169), typing the barcode in 1.0% (1589 cases), and searching by pill imprint in 0.9% (1461 cases, or 3.4% of 43,011 cases involving pills). Substance identification through barcode scanning increased over time, from 3.0% of cases in Jan 2020 to 3.8% in Dec 2020. By the end of 2020, there were 868,000 barcodes attached to substances and available for users who chose to scan or type barcodes for substance selection (and over 1.07 million barcodes attached by December 2021).

web**POISON**CONTROL databases are continuously growing, with new algorithms, substances, and barcodes (UPCs) added daily. At the end of 2020, there were 2112 active algorithms, and 78% of these were used to provide recommendations to public users during the year. At the end of 2020, there were 112,463 substances in the database with all ingredients matched to algorithms, ready for user selection; 21% of these were used in completed, nonduplicated public cases during the year.

4. Discussion

Poison control services have traditionally been provided via telephone in the United States, but an internet-driven paradigm shift in the methods of acquisition and delivery of health-related information in the United States has created the need for alternative options for poison control services. The web**POISON**CONTROL tool provides a reliable alternative source of information for those who are unable or unwilling to use the telephone to call traditional poison control centers. The tool is a safe and robust supplement to traditional telephonic poison control and is intended to complement, not replace, traditional poison control services. By design, web**POISON**CONTROL was intended to address common and uncomplicated poison exposures, referring complex and severe cases to poison centers for more specialized recommendations by trained healthcare providers. Triage recommendations provided by web**POISON**CONTROL are utilized by many poison centers to inform poison specialists' triage and at-home management decisions, resulting in a level of harmonization of recommendations. The data show the most common substance categories (cosmetics, cleaning substances, analgesics, dietary supplements/herbals/homeopathics) implicated in web**POISON**CONTROL exposures are similar to those implicated in traditional poison center exposure cases ([7], NPDS data disclosure statement). web**POISON**CONTROL outcomes are similar to traditional poison center case outcomes, predominantly that of "no effect", "minor effect", and "minimally toxic (or nontoxic) with unknown outcome" [7]. This consistency illustrates the safety of web**POISON**CONTROL recommendations.

There are interesting similarities and differences between online users of poison control services (through web**POISON**CONTROL) and those who seek poison control services by telephone. In 2020, web**POISON**CONTROL handled 156,202 cases, about 7.3% as many human poison exposure cases as were reported to phone-based poison centers [7]. A slight female predominance was observed in both databases, evident in patients over age 12. The age distribution differed however, with 53% of web**POISON**CONTROL cases occurring in children younger than 4 years, compared to only 37% of telephone-based poison center cases (chi-square, $p < .00001$) [7]. These findings are consistent with predictors of the use of online sources for health information including younger age, higher internet skills, and female gender [8,9]. Parents of young children today are themselves likely to be in their 20s to early 30s and comprise a cohort that has largely had access to computers, mobile devices, and the internet for much of their lives. Nonpharmaceuticals were implicated in 58.5% of web**POISON**CONTROL cases compared to 43.5% of substances implicated in 2020 human poison exposures reported by telephone in the U.S. [7], although a direct comparison is hampered by the single substance limit in web**POISON**CONTROL. Of web**POISON**CONTROL cases triaged to home, follow-up was obtained in 33.3% of cases, compared to an estimated 22% of phone-based reports, or about 50% more often, based on 2018 benchmarking data using definitive outcomes as a marker for poison control follow-up [10]. Assuming the followed cases were representative of all cases, user compliance with web**POISON**CONTROL recommendations to stay home rather than go to an ED was high, with only 0.45% of those advised to stay home subsequently indicating they eventually went to an ED. Despite expected under-reporting, this compliance rate is comparable to a 2001 study of callers to the New Zealand National Poisons Centre that showed a noncompliance rate of 1.3% for callers advised to stay home (and a noncompliance rate of 23.9% for callers advised to go to the hospital) [11]. Likewise, an analysis from the Ontario Regional Poison Center showed that 6.6% of those advised that no treatment was needed failed to heed poison center advice [12].

Of 3875 surveyed users in 2020, 96.7% described web**POISON**CONTROL as "very quick or quick" and 98.1% as "easy or somewhat easy". The median time to receive a recommendation (2.7 min) compares favorably with the limited published data on time to recommendation for telephone-based poison control cases. Beuhler described a 7.4 min mean time for cases managed outside of a healthcare facility [13]. However Beuhler's study was designed to evaluate poison center staff workload, and therefore included documentation time but not time spent by callers in a phone queue or on hold. web**POISON**CONTROL cases do not require additional documentation time and there is no queue for a web-based app. Further, a sampling of inbound call time for 3 poison centers showed a range of 3 min 57 s to 7 min 23 s for inbound call time, including time to answer, talk time and hold time (Nicole Reid, personal communication, November 2021).

Traditional poison control center data are underreported and often correlate poorly with other repositories, including medical examiner and poisoning fatality databases [14-17]. In a 2000 study, deaths reported to poison control centers represented only 5% of poisoning-related deaths compiled by the National Center for Health Statistics [18]. The United States Centers for Disease Control and Prevention (CDC) reported that over 70% of the nearly 71,000 drug overdose deaths in 2019 involved an opioid, yet only 289 opioid-related fatalities were reported by NPDS in 2019 [7,19]. Cases collected by web**POISON**CONTROL represent another cross-sectional view of poisoning exposures, adding to the perspective provided by poisoning fatality databases (CDC's WISQARS™ [20], CDC's NVSS [21]), ED- based product injury databases (Consumer Product Safety Commission's NEISS [22]), ED injury/visit databases (CDC's NAMCS [23]), and NPDS [7]. The collaborative utilization of all these databases is critical for performing urgent public health functions such as hazard detection and surveillance. Increases in web**POISON**CONTROL cases involving hand sanitizers, disinfectants, and cleaning products, associated with the COVID-19 pandemic events of early 2020, illuminate how the public seeks information during a public health crisis in an uncertain environment and illustrate the hazard detection capabilities of web**POISON**CONTROL.

Multiple studies have estimated a cost savings of $6 to $36 per dollar spent providing poison control service [24,25]. That savings derives in large part from avoidance of unnecessary ED visits. From 2008 to 2020, the population-adjusted utilization of U.S. telephone-based poison control centers fell by 22%, possibly jeopardizing the important role of poison centers in preventing the unwarranted overutilization of ED's for poison exposures. Since 2017, as use of web**POISON**CONTROL increased, the utilization of traditional poison control centers has remained relatively stable (Fig. 8). The temporal association of this stabilization suggests that web**POISON**CONTROL has not caused an erosion in poison control call volume. In 2020 alone, more than half a million web**POISON**CONTROL users were referred to phone-based poison centers, including 478,079 referred prior to case completion in the app and 44,439 completed cases referred by the app. While a temporal association is not proof of causality, web**POISON**CONTROL may have helped stabilize poison control call volume while simultaneously capturing additional exposures that NPDS would otherwise have missed.

5. Limitations

web**POISON**CONTROL is intentionally designed to focus on the triage and treatment of less serious poison exposures, as some poison exposures are too complex, nuanced, or serious to be managed without the assistance of a qualified poison specialist, medical toxicologist, ED and/or ICU. To optimize patient safety, the triage algorithms are intentionally written to err on the side of over-referring to traditional poison control centers, even if only to confirm that an ED visit is truly required for the individual case. While follow-up of home-triaged cases was robust and more frequent than that of traditional poison centers, 26.7% of cases had potentially toxic exposures without a definitive outcome determination because they were referred to call Poison Control or go to an ED. These were cases where the user did not log back in to provide follow-up because the app was designed to suppress timely follow-up reminders for these referrals and instead assume that care had been transferred and that further contact might lead to conflicting recommendations.

6. Conclusion

The web**POISON**CONTROL app and browser-based tool represent an adjunctive method of collecting poisoning data that can augment the existing case information obtained through traditional poison control centers. This analysis of 156,202 cases revealed that cosmetics, cleaning substances, analgesics, and dietary supplements were the most commonly reported exposures to web**POISON**CONTROL in 2020. Similar to cases managed by traditional poison centers, most cases are triaged to home management and had “no effect”, “minor effect”, or “unknown minimally toxic” outcomes. The data affirm the effectiveness, speed and safety of webPOISON**CONTROL**'s recommendations. While web**POISON**CONTROL was developed to meet the public's need for internet-based poison control services, its analytics dashboard provides near real-time analyses of toxic exposures that can enhance public health surveillance and hazard detection. web**POISON**CONTROL is also an advantageous source of product, triage and treatment information for poison control centers, offering more than 2300 algorithms and an opportunity to harmonize poison control triage across the U.S. The tool also offers untapped, low- or no-cost surge capacity for poison centers facing disasters or coping with high call volumes from public health events. As public use of internet-based health information resources increases even further, we anticipate that web**POISON**CONTROL will

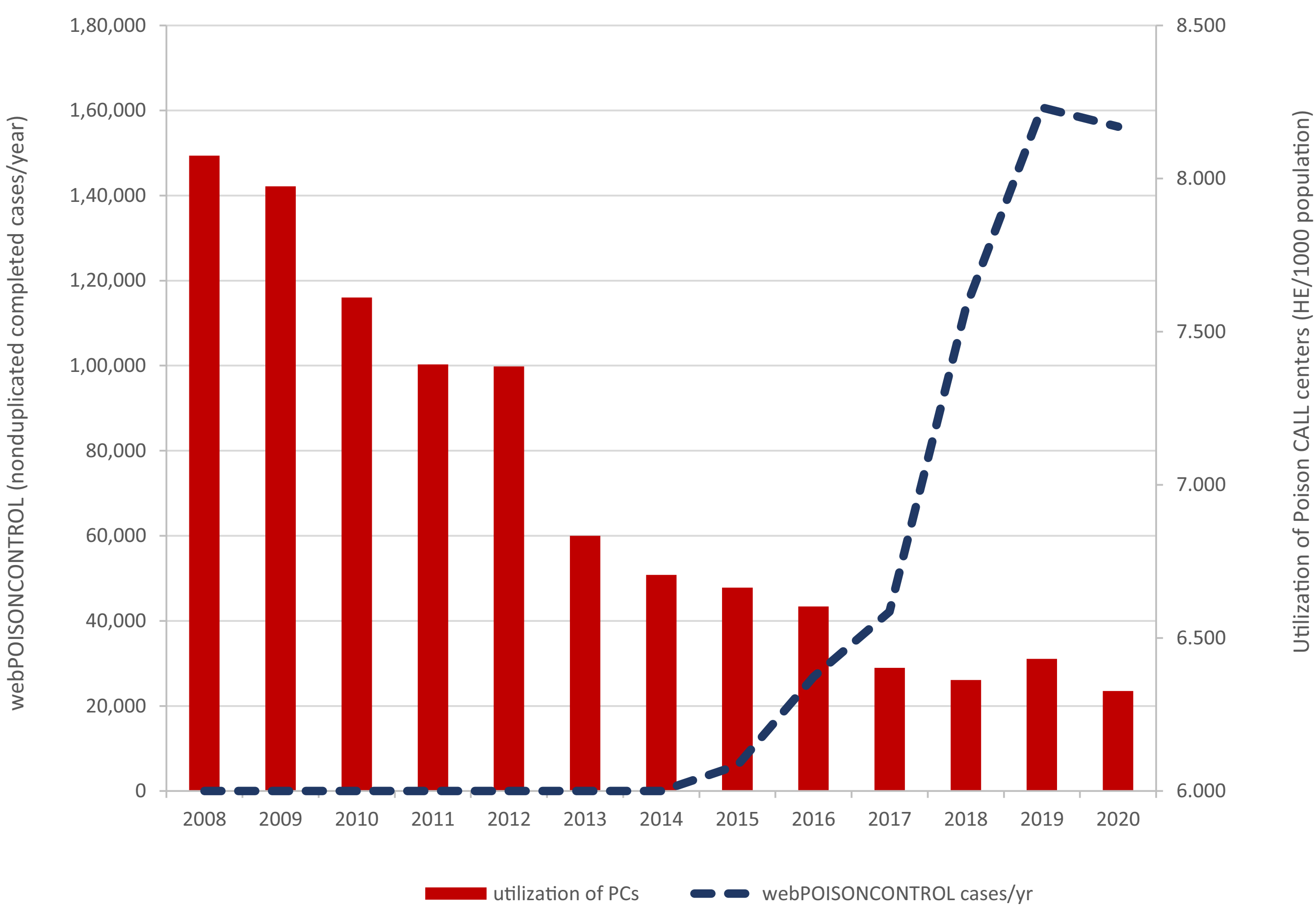

Fig. 8. Utilization of U.S. poison control centers (human exposures[HE]/1000 population, by phone) compared to web**POISON**CONTROL nonduplicated, completed public case volume.

continue to evolve and assume an expanding role in the prevention, triage and treatment of human poison exposures in the U.S.

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Credit authorship contribution statement

Nicole E. Reid: Writing – review & editing, Validation, Methodology, Formal analysis, Data curation, Conceptualization. **Kelly Johnson-Arbor:** Writing – review & editing, Writing – original draft, Methodology, Data curation, Conceptualization. **Susan Smolinske:** Writing – review & editing, Methodology, Data curation, Conceptualization. **Toby Litovitz:** Writing – review & editing, Writing – original draft, Visualization, Project administration, Methodology, Formal analysis, Data curation, Conceptualization.

Declaration of Competing Interest

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References

[1] Scherz RG, Robertson WO. The history of poison control centers in the United States. Clin Toxicol. 1978;12(3):291–6. https://doi.org/10.3109/15563657809150481.

[2] Lovejoy Jr FH, Robertson WO, Woolf AD. Poison centers, poison prevention, and the pediatrician. Pediatrics. 1994;94(2 Pt 1):220–4.

[3] Gummin DD, Mowry JB, Beuhler MC, Spyker DA, Bronstein AC, Rivers LJ, et al. 2020 annual report of the American Association of Poison Control Centers' National Poison Data System (NPDS): 38th annual report. Clin Toxicol. 2021;59(12):1282–501. https://doi.org/10.1080/15563650.2021.1989785.

[4] Tan SS, Goonawardene N. Internet health information seeking and the patient-physician relationship: a systematic review. J Med Internet Res. 2017.;19(1):e9. https://doi.org/10.2196/jmir.5729.

[5] Zhao X, Coxe SJ, Timmons AC, Frazier SL. Mental health information seeking online: a Google trends analysis of ADHD. Admin Pol Ment Health. 2021 Sep 22. https://doi.org/10.1007/s10488-021-01168-w. Online ahead of print.

[6] Litovitz T, Benson BE, Smolinske S. webPOISONCONTROL: can poison control be automated? Am J Emerg Med. 2016;34(8):1614–9. https://doi.org/10.1016/j.ajem.2016.06.018.

[7] American Association of Poison Control Centers. National Poison Data System. www.aapcc.org. [Accessed 24 Oct 2021] Restricted access database.

[8] Jacobs W, Amuta AO, Jean KC. Health information seeking in the digital age: an analysis of health information seeking behavior among US adults. Cogent Social Sci. 2017;3:1302785. https://doi.org/10.1080/23311886.2017.1302785.

[9] Li J, Theng Y-L, Foo S. Predictors of online health information seeking behavior: changes between 2002 and 2012. Health Informat J. 2016;22(4):804–14. https://doi.org/10.1177/1460458215595851.

[10] Colvin J, Scharman E. Designing the benchmarks for: Staffing workload and productivity measures. AAPCC benchmarking committee report. (Unpublished AAPCC internal report.) Midyear Meeting, Phoenix; 2020.

[11] Watts M, Fountain JS, Reith D, Schep L. Compliance with poisons center referral advice and implications for toxicolvigilance. J Toxicol Clin Toxicol. 2004;42(5):603–10. https://doi.org/10.1081/clt-200026972.

[12] Yamada J, McGuigan M. Parent and caregiver compliance with poison center advice. J Toxicol Clin Toxicol. 2001;39(3):201–3. https://doi.org/10.1081/clt-100104523.

[13] Beuhler MC, Thomas C. Time requirements for management of exposure and information cases by one regional poison center. Clin Toxicol. 2020;58(7):732–5. https://doi.org/10.1080/15563650.2019.1676897.

[14] Harchelroad F, Clark RF, Dean B, Krenzelok EP. Treated vs reported toxic exposures: discrepancies between a poison control center and a member hospital. Vet Hum Toxicol. 1990;32(2):156–9.

[15] Soslow AR, Woolf AD. Reliability of data sources for poisoning deaths in Massachusetts. Am J Emerg Med. 1992;10(2):124–7. https://doi.org/10.1016/0735-6757(92)90043-w.

[16] Linakis JG, Frederick KA. Poisoning deaths not reported to the regional poison control center. Ann Emerg Med. 1993;22(12):1822–8. https://doi.org/10.1016/s0196-0644(05)80408-1.

[17] Blanc PD, Kearney TE, Olson KR. Underreporting of fatal cases to a regional poison control center. West J Med. 1995;162(6):505–9.

[18] Hoppe-Roberts JM, Lloyd LM, Chyka PA. Poisoning mortality in the United States: comparison of national mortality statistics and poison control center reports. Ann Emerg Med. 2000;35(5):440–8.

[19] Centers for Disease Control and Prevention. Drug Overdose Deaths. https://www.cdc.gov/drugoverdose/deaths/index.html; 2021. [accessed 23 Oct 2021].

[20] Centers for Disease Control and Prevention, National Centers for Injury Prevention and Control. Web-based Injury Statistics Query and Reporting System (WISQARS). www.cdc.gov/injury/wisqars; 2020. [accessed 18 Nov 2021].

[21] Centers for Disease Control and Prevention, National Center for Health Statistics. National Vital Statistics System (NVSS). https://www.cdc.gov/nchs/nvss/; 2021. [accessed 11 Nov 2021].

[22] U.S. Consumer Product Safety Commission. National Electronic Injury Surveillance System (NEISS). https://www.cpsc.gov/Research–Statistics/NEISS-Injury-Data; 2021. [accessed 11 Nov 2021].

[23] Centers for Disease Control and Prevention, National Center for Health Statistics. National Ambulatory Medical Care Survey (NAMCS). https://www.cdc.gov/nchs/namcs/hcc/participant.htm; 2021. [accessed 15 Nov 2021].

[24] LoVecchio F, Curry S, Waszolek K, Klemens J, Hovseth K, Glogan D. Poison control centers decrease emergency healthcare utilization costs. J Med Toxicol. 2008;4(4):221–4. https://doi.org/10.1007/BF03161204.

[25] Miller TR, Lestina D. The costs of poisoning in the U.S. and the savings from poison control centers: a benefit-cost analysis. Ann Emerg Med. 1997;29(2):239–45. https://doi.org/10.1016/s0196-0644(97)70275-0.