Supplemental Information

METHODS (continued)

NPDS

The impact of annual variations in poison center utilization on incidence was tested and found to be minimal (mean incidence adjustment: 5.0% [range: 0.5%–11.7%]); thus, utilization adjustments were not made.

NBIH

Ingestions by pets and batteries in the ear, nose, or vagina were excluded. Analyses according to year were based on the date reported. When possible, follow-up was conducted until the battery passed and clinical effects resolved, sometimes over years. Battery-discharge state (new, partially spent, spent) was determined from the caller's assessment of battery usage. The standardized poison control data set for all NBIH cases was also submitted to NPDS (without the additional NBIH clinical and battery detail).

NBIH callers were asked to mail batteries to the center, where 1 evaluator (Dr Litovitz) confirmed the imprint code and scored the extent of corrosion (1–5 scale, applied to the most corroded cell if multiple cells were ingested).

NBIH medical outcome definitions were adapted from NPDS, as follows:

No effect: no signs or symptoms from the ingestion.

Minor effect: minimally bothersome signs or symptoms resolved rapidly without residual disability or disfigurement (eg, transient nausea, vomiting, abdominal pain, irritability, fever, rash, or darkened stools without blood).

Moderate effect: more pronounced, prolonged, or multiple signs or symptoms (eg, blood in the stool or emesis, or documented mucosal burns, without sequelae).

Major effect: life-threatening signs or symptoms or significant residual disability resulted from the ingestion (eg, mucosal burns with protracted healing and/or long-term sequelae, systemic effects, perforations, or fistulas).

Death: fatality related to the ingestion.

Unknown: inadequate follow-up to determine outcome.

Unrelated: clinical effects attributed to other causes.

NBIH statistical analysis was conducted with SAS (SAS Institute, Inc, Cary, NC). Logistic regression models were developed to determine outcome predictors, with outcome dichotomized as clinically significant (moderate, major, or death) or benign (no or minor effect). No attempt was made to distinguish between outcomes of lithium manganese dioxide (CR, or occasionally DL, imprint prefix) and lithium carbon monofluoride (BR prefix) cell ingestions, because most cases involved the lithium manganese dioxide chemistry (CR).

RESULTS (continued)

GUT TRANSIT TIMES AND USE OF EMETICS, ENDOSCOPY, AND SURGERY (NBIH)

Fifty-seven patients (0.7%) were given emetics or gagged to induce vomiting; however, the battery was expelled in only 4 of these cases (7.0%). The interval for battery passage through the gastrointestinal tract was known and occurred without surgical or endoscopic intervention in 4887 patients (56.5%). Of these patients, 63.6% passed the battery in $<$72 hours, 74.3% in $<$96 hours, and 95.9% in $<$14 days (see Table 8). Of the 1% of patients for whom battery passage required $\geq$1 month, most were elderly (67% of those with known age were $\geq$65 years of age) and involved small batteries (65% $\leq$ 7.9 mm).

Endoscopy was documented in 481 cases (6.2% of cases when known if performed), most often for batteries in the stomach (57.2%) or esophagus (26.2%). Removal attempts failed when batteries had progressed beyond the reach of the endoscope. Impacted batteries and batteries that could not be grasped securely often led to lengthy procedures, referrals for another endoscopic attempt, or (rarely) operative removal. Mucosal ulcerations, superficial erosions, and batteries tightly adherent to the mucosa were occasionally described for batteries beyond the esophagus, nearly always without sequelae. Surgery was performed for 46 battery ingestions (0.59% of cases when known if surgery was performed).

In contrast, for children younger than 6 years who ingested 20- to 25-mm-diameter cells (238 cases), endoscopy was performed in 48.2% (of 226 cases where known whether endoscopy was performed). Of these pediatric battery retrievals, 53.2% were from the esophagus and 45.9% were from the stomach. Of 32 cases with endoscopic removal attempted from the stomach and known mucosal findings, 75% had no lesions, 9.4% (3) had ulceration without perforation or sequelae, and 15.6% (5) had minor superficial erosions. Large batteries (20–25 mm), left to pass through the gut of these young children without endoscopic retrieval, passed in about twice the median time (83.5 hours for 20- to 25-mm cells compared with 42 hours

for all other diameter cells; $P < .0001$, Mann-Whitney test).

BATTERY CORROSION AND OUTCOME

Twenty-one percent of ingested cells (1809 batteries) were examined at the NBIH after passage or retrieval. The extent of corrosion was scored on the basis of the percentage of the battery crimp (portion of the can adjacent to the seal) that had corroded away, the extent of pitting, and whether the cell had split in half (because of extensive crimp dissolution). Corrosive changes were scored as (1) virtually no change other than discoloration (10.1% of cells sent in for assessment), (2) crimp dissolution of <10% or mild-to-moderate pitting (22.0%), (3) diffuse pitting and/or 10% to 50% crimp dissolution (53.7%), (4) crimp dissolution of >50%, battery split after passage, or a large perforation of the can (12.6%), and (5) battery split in the gastrointestinal tract (1.5%). Each 1-point increase in condition score, which reflected greater corrosion, was associated with a 1.5-times greater likelihood of a severe outcome (logistic regression, $P = 0.015$, $n = 1699$). Of patients with severe crimp dissolution or split cells (scores 4 or 5), 4.2% had severe outcomes compared with 1.2% of those without corrosive damage of the ingested cell.

REVIEW OF FATALITIES AND MAJOR OUTCOME CASES FROM THE NBIH AND THE MEDICAL LITERATURE

Reports of button cells causing burns in the esophagus or airway resulting in major (73) or fatal outcomes (13) were retrieved from the NBIH, the medical literature, and the media.

Fatal Ingestions

Batteries implicated in the 13 fatal cases included 23-mm manganese dioxide cells (PX 825, no longer marketed, 2 cases),[1,2] 20-mm lithium cells (CR 2032, 4 cases; CR 2025, 1 case), a 15-mm cell (1 case), and 5 with unknown diameters. Batteries were in the esophagus for 10 hours to 2 weeks before removal or death (≤2 days, 5 cases; 4 days to 2 weeks, 7 cases; unknown, 1 case). Interval estimates, based on symptom onset in unwitnessed ingestions, may underestimate the duration of esophageal lodgment if initially asymptomatic. The battery was lodged in the upper or midesophagus in most fatal cases.

Twelve of the 13 fatal cases showed evidence of bleeding. Exsanguination and shock caused by esophageal fistulas involving major arteries occurred in 9 patients, including 7 with aortoesophageal fistulas,[2–5] 1 involving the inferior thyroid arteries and veins,[1] and an esophageal-right subclavian artery fistula. Local or massive bleeding from smaller or unidentified vessels contributed to the death of 3 additional patients. Delayed, unanticipated, and uncontrollable massive bleeding occurred 1, 2, 4, 5, 8, 10, and 18 days after battery removal. Tracheoesophageal fistulas were identified in 4 fatal cases[1,6] and pneumothorax and pneumoperitoneum in one case.[7]

Major Outcome Ingestions

When battery diameter was known (64 cases), 90.6% were ≥20 mm, 4 were 11.6 mm, and 2 were 15.6 to 16 mm. The imprint code was available for 42 (57.5%) of the 73 major outcome cases, and lithium cells CR 2032 (50% of cases with known imprint), CR 2025 (16.7%), and CR 2016 (7.1%) were the most commonly implicated. Three additional cases had similar imprints (BR 2016, DL 2025, DL 2032). Four early ingestions involved 23-mm EPX or PX 825 cells.

The battery was lodged in the upper or midesophagus (84.9%), distal esophagus (4.1%), airway (2.7%), or an unknown esophageal position (8.2%).

Ten patients resumed normal feeding within 2 months, 25 in 2 months to 1 year, 10 in ≥1 year, and 7 in 2 to >7 years (unknown interval for 21).

REVISED TRIAGE AND TREATMENT GUIDELINE

Children Younger Than 6 Years With ≥15-mm Button Cell Retained in Stomach

Data addressing the percentage of large-diameter button cells that will spontaneously pass the pylorus and the incidence of gastric ulcerations are confounded by early intervention; nearly one-quarter of 20- to 25-mm cells located in the stomach were removed. Yet, it is not known if that removal was required, because no serious complications occurred in this group, and of those batteries left to pass spontaneously, more than half did so within 4 days (these large cells pass through the gut about twice as slowly as smaller cells).

Co-ingested Battery and Magnet

Prompt removal is required if a battery and magnet are co-ingested. If removal occurs early before damage occurs, the clinician has the option of removing only the battery or the magnet if only one can be retrieved endoscopically.

Ineffective Interventions

A number of once-advocated interventions are now known to be ineffective or unnecessary. Ipecac rarely expels the battery and should not be used. Animal data have shown that laxatives are ineffective.[8] Polyethylene glycol electrolyte solution should be studied to determine whether it hastens elimination or worsens damage by enhancing electrolysis. Metoclopramide is occasionally recommended to advance batteries retained in the stomach, but its efficacy has not been confirmed. Determinations of blood or urine concentrations of mercury or other battery

ingredients and chelation therapy are unnecessary.

LIMITATIONS

Poison-center reporting is voluntary; thus, many cases are not reported. In addition, NBIH and NPDS data are gathered during telephone consultations, often with parents or patients, with incomplete access to detailed medical information. These limitations were mitigated for serious cases, when possible, through extensive telephone follow-up, contact with both health professionals and parents, and review of endoscopy or operative reports.

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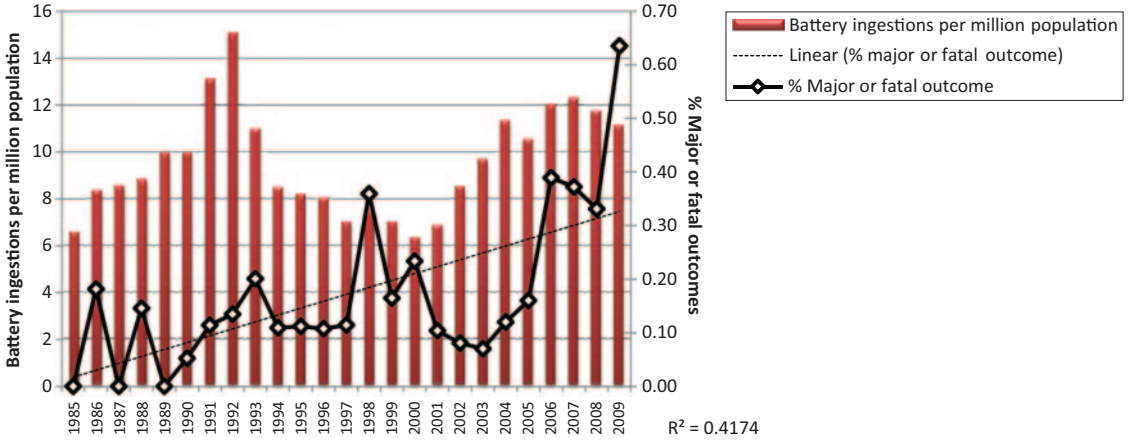

FIGURE 5
NPDS button battery ingestion frequency and severity (major and fatal outcomes) according to year.

TABLE 5 Button Battery Ingestions Reported to the National Poison Data System, 1985–2009

Year	Population Served by Participating Poison Centers, Millions	No. of Ingestions	Ingestions per Million Population	<6 y, *n*	6–19 y, *n*	>19 y, *n*	Treated in HCF, *n*	Outcome, *n*					% Major or Death	% Moderate, Major, or Death
								No Effect	Minor	Moderate	Major	Death		
1985	113.6	745	6.56	540	134	41	475	492	52	3	0	0	0.0000	0.4027
1986	132.1	1101	8.33	849	144	87	702	764	60	6	2	0	0.1817	0.7266
1987	137.5	1172	8.52	859	187	98	759	864	91	7	0	0	0.0000	0.5973
1988	155.7	1371	8.81	1009	210	125	987	972	85	8	2	0	0.1459	0.7294
1989	182.4	1817	9.96	1302	327	141	1220	1232	104	5	0	0	0.0000	0.2752
1990	191.7	1909	9.96	1433	293	146	1322	1195	101	5	1	0	0.0524	0.3143
1991	200.7	2627	13.09	2032	356	178	1876	1535	139	6	3	0	0.1142	0.3426
1992	196.7	2969	15.09	2416	342	146	2091	1726	146	9	4	0	0.1347	0.4379
1993	181.3	1991	10.98	1515	299	158	1426	1165	74	16	4	0	0.2009	1.0045
1994	215.9	1829	8.47	1301	330	186	1234	1034	68	12	2	0	0.1093	0.7654
1995	218.5	1786	8.17	1225	358	191	1272	1049	81	13	2	0	0.1120	0.8399
1996	232.3	1859	8.00	1224	409	216	1227	1017	99	17	2	0	0.1076	1.0221
1997	250.1	1747	6.99	1130	393	216	1150	916	63	15	2	0	0.1145	0.9731
1998	257.5	1946	7.56	1226	472	240	1300	1074	63	12	6	1	0.3597	0.9764
1999	260.9	1821	6.98	1105	464	243	1210	1003	62	11	3	0	0.1647	0.7688
2000	270.6	1711	6.32	1057	389	259	1150	854	53	16	4	0	0.2338	1.1689
2001	281.3	1923	6.84	1200	424	288	1256	993	75	21	2	0	0.1040	1.1960
2002	291.6	2478	8.50	1463	709	292	1609	1196	99	29	2	0	0.0807	1.2510
2003	294.7	2848	9.66	1735	800	297	1860	1426	115	20	2	0	0.0702	0.7725
2004	293.7	3331	11.34	2082	910	315	2152	1647	126	31	4	0	0.1201	1.0507
2005	296.4	3119	10.52	2090	699	308	2123	1494	101	34	4	1	0.1603	1.2504
2006	299.4	3594	12.00	2411	748	413	2488	1668	160	71	13	1	0.3895	2.3651
2007	305.6	3758	12.30	2449	785	494	2730	1840	167	84	14	0	0.3725	2.6078
2008	308.3	3622	11.75	2442	663	477	2599	1670	188	80	12	0	0.3313	2.5400
2009	311.0	3461	11.13	2410	607	428	2599	1677	201	75	18	4	0.6357	2.8027
Total		56 535	9.62	38 505	11 452	5983	38 817	30 503	2573	606	108	7	0.2034	1.2753

TABLE 6 Button Battery Ingestions in Children Younger Than 6 Years Reported to the National Poison Data System, 1985–2009

Year	Population Served by Participating PCs, Millions	No. of Ingestions <6 y	Treated in HCF, *n*	Outcome, *n*					% Moderate, Major, or Death
				No Effect	Minor	Moderate	Major	Death	
1985	113.6	540	354	381	34	0	0	0	0.0000
1986	132.1	849	535	610	43	5	2	0	0.8245
1987	137.5	859	558	649	69	5	0	0	0.5821
1988	155.7	1009	737	738	60	6	2	0	0.7929
1989	182.4	1302	882	917	71	1	0	0	0.0768
1990	191.7	1433	1003	926	71	3	0	0	0.2094
1991	200.7	2032	1466	1222	93	4	3	0	0.3445
1992	196.7	2416	1725	1461	115	9	3	0	0.4967
1993	181.3	1515	1120	899	57	11	3	0	0.9241
1994	215.9	1301	881	734	52	6	2	0	0.6149
1995	218.5	1225	899	746	56	8	1	0	0.7347
1996	232.3	1224	823	677	56	11	1	0	0.9804
1997	250.1	1130	743	608	35	10	2	0	1.0619
1998	257.5	1226	838	690	37	5	5	0	0.8157
1999	260.9	1105	758	624	45	6	1	0	0.6335
2000	270.6	1057	734	560	32	7	3	0	0.9461
2001	281.3	1200	811	636	55	15	1	0	1.3333
2002	291.6	1463	978	731	58	20	2	0	1.5038
2003	294.7	1735	1149	897	64	11	1	0	0.6916
2004	293.7	2082	1365	1060	74	23	4	0	1.2968
2005	296.4	2090	1435	1039	57	19	3	1	1.1005
2006	299.4	2411	1706	1145	86	31	7	1	1.6176
2007	305.6	2449	1825	1269	89	37	8	0	1.8375
2008	308.3	2442	1825	1215	97	35	8	0	1.7609
2009	311.0	2410	1864	1233	121	35	13	4	2.1577
Total		38 505	27 014	21 667	1627	323	75	6	1.0492

TABLE 7 Logistic Regression Model of Variables Associated With Moderate, Major, or Fatal Outcomes ($N = 4307$)

Variable	β	SE	Wald Statistic	*P*	OR	Confidence Interval
Diameter 20–25 mm	3.2	0.19	269.8	<.0001	24.59	16.78–36.02
Age <4 y	1.2	0.22	29.3	<.0001	3.24	2.12–4.95
>1 battery ingested	0.7	0.31	5.8	.016	2.12	1.15–3.90
Male gender	0.4	0.20	4.2	.042	1.49	1.02–2.18

National Battery Ingestion Hotline data (Jul 1990-Sept 2008, only). Outcome dichotomized as clinically significant (moderate, major or death) and benign (no or minor effect).

TABLE 8 Time Required for Spontaneous Passage Through the Gastrointestinal Tract (NBIH)

Interval to Passage	*n*	%	% of Known	Cumulative	Cumulative % of Known
<24 h	730	8.44	14.94	730	14.94
≥24 h, <48 h	1448	16.74	29.63	2178	44.57
≥48 h, <72 h	930	10.75	19.03	3108	63.60
≥72 h, <96 h	521	6.02	10.66	3629	74.26
≥96 h, <120 h	286	3.31	5.85	3915	80.11
≥120 h, <144 h	213	2.46	4.36	4128	84.47
≥144 h, <168 h	135	1.56	2.76	4263	87.23
≥168 h, <192 h	130	1.50	2.66	4393	89.89
≥192 h, <216 h	76	0.88	1.56	4469	91.45
≥216 h, <240 h	58	0.67	1.19	4527	92.63
≥240 h, <336 h (14 d)	162	1.87	3.31	4689	95.95
≥336 h, <30 d (720 h)	151	1.75	3.09	4840	99.04
≥30 d	47	0.54	0.96	4887	100.00
Unknown	3761	43.49	—	8648	—
Total	8648	—	100.00	—	—