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ORIGINAL ARTICLE

Gastroenterology

The effects of liquid bleach ingestion on children's esophageal and gastric mucosa

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Abstract

Objectives: The ingestion of caustic substances is currently a significant health concern in pediatric age, being bleach products among the most commonly ingested. The management of children having ingested bleach is currently controversial since scientific data on their degree of toxicity toward the esophageal and gastric mucosa are currently very poor. Therefore, our study aims at comprehensively analyzing the effects of bleach ingestion in children as well as at evaluating patterns of ingestions, clinical symptom development, and endoscopic findings.

Methods: This prospective observational study was carried out between January 2017 and December 2023 at the Pediatric Department of Santobono Children's Hospital in Naples. Children aged 0–18 years admitted for bleach ingestion were enrolled.

Results: One hundred children with a mean age of 58.7 months were included in the study. Eighty-nine/100 (89%) children had ingested household bleaches (both chlorine- or peroxidase-based) while 11/100 (11%) had ingested homemade or industrial bleaches. The latter were significantly more likely to develop esophagogastric lesions, while children having ingested commercially available household bleaches did not report significant mucosal lesions.

Conclusions: Our data suggest that the toxicity of commercially available household bleaches on the gastrointestinal tract is very low. Therefore, digestive endoscopy is generally unnecessary in case of household bleach ingestion. Conversely, a timely endoscopic evaluation and close follow-up should be performed in children who ingest homemade or industrial bleaches.

KEYWORDS

accidental ingestion, caustic, digestive endoscopy

1 | INTRODUCTION

The ingestion of caustic substances is a common medical problem in childhood.[1–3] According to the Center for Disease Control and Prevention (CDC), caustic substances are chemicals that lead to burns or corrosions when coming into contact with human tissues.[4] Caustic substances are commonly defined by their pH level as acids or alkalis, depending on whether they have a pH lower than 2 or higher than 12.[1]

Among caustic substances, bleach is one of the most frequently ingested class of products.[4–6] Bleach refers to a broad category of alkaline substances utilized for whitening materials, most commonly within the

scope of cleaning and disinfection. Bleaches can be categorized into three groups: chlorine-based (NaOCl) bleaches, peroxidase-based (H_2O_2) bleaches and artisanal or industrial bleaches with higher or unknown concentrations.[7] Sodium hypochlorite is an oxidizing agent, whose toxicity is related to its oxidizing capacity and the pH of the associated solution.[8] Hydrogen peroxide may cause toxicity with different mechanisms such as corrosive damage, oxygen gas formation and lipid peroxidation.[9]

Within the clinical management of a child having ingested a caustic substance, clinical signs and symptoms may not always be good predictors of the degree of mucosal injury and possible outcome of stricture formation.[10] When mucosal lesions are suspected, upper gastrointestinal endoscopy is the gold-standard diagnostic technique to establish the severity and extent of the mucosal damage caused by caustic ingestion.[11]

To date scientific data on the degree of toxicity of bleaches towards the esophageal and gastric mucosa are currently very poor, especially in pediatric age.[11,12] It has been recently reported that household bleach ingestion cause no or low-grade esophagitis in adults.[13] These data have not yet been confirmed in pediatric age. Therefore, to date, there is no common agreement on how to best manage this occurrence in pediatric population with regard to the need for gastrointestinal endoscopy, medical treatment, and hospitalization. The recommendations of national and international guidelines about the management of their ingestions are usually evasive and not specific.[11,14]

The main aim of this prospective study was to evaluate the effects of bleach ingestion on the esophageal and gastric mucosa in children. Secondary aims were to analyze bleach ingestion patterns, clinical symptoms, endoscopic findings, and long-term clinical outcomes of this group of children.

What is Known?

- The ingestion of caustic substances is a common medical problem in childhood.
- Among caustic substances, bleach is one of the most frequently ingested class of products.
- To date scientific data on the degree of toxicity of bleaches towards the esophageal and gastric mucosa are currently very poor, especially in pediatric age.
- Accidental ingestion of bleach by children is a current issue whose management is still controversial.

What is New?

- Our data suggest that the toxicity of commercially available bleaches (NaOCL-based and H_2O_2-based) on the gastrointestinal tract is very low and comparable to that of other household products generally considered safe.
- Conversely, a timely endoscopic evaluation and close follow-up should be performed in children who ingest homemade or industrial bleaches, since H_2O_2 and NaOCl concentrations could be much higher and mucosal injuries more likely.

2 | METHODS

This prospective observational study was conducted from January 2017 to December 2023 at the Pediatric Department of the Santobono Children's Hospital in Naples. All children aged 0–18 years referred for ingestion of bleach were prospectively enrolled.

Patients were divided into three groups according to the type of ingested bleach: Group 1, children who had ingested household chlorine-based bleach; Group 2, children who had ingested household peroxidase-based bleach; Group 3, children who had ingested artisanal or industrial bleaches. The product pH level was assessed in the Emergency Department using litmus paper testing if the product was accessible, or by identifying the ingested substance and retrieving its safety data sheet, or by contacting the National Poison Center.

Data on age, gender, caustic ingested, commercial name of the bleach, chemical properties and concentration of the bleach product, date and time of ingestion, amount ingested, time of last meal, clinical signs and symptoms arisen after the ingestion and medical intervention were recorder for each enrolled chidren. Modalities of ingestion such as accidental, accidental-deliberate or voluntary, were also reported. Comorbidities such as neurologic and psychiatric disorders were screened. Furthermore, any possible measures taken at home to prevent damage were recorded, such as inducing vomiting and liquids or drug administration.

In accordance with the latest guidelines, endoscopic evaluation was performed in all symptomatic children and asymptomatic individuals with documented caustic ingestion.[10,15] Esophagogastroduodenoscopy (EGD) was performed under general anesthesia by experienced pediatric endoscopists and explored the esophagus, the stomach and the duodenum. Esophageal lesions identified during the endoscopic examination were classified according to the Zargar's score (Table 1).[16]

Patients displaying respiratory symptoms were referred to a pediatric otolaryngologist for a laryngoscopic evaluation. A comprehensive set of blood tests, including a complete blood cell count, biochemical parameters, C-reactive protein, and arterial blood gas values, was performed in all children at the time of admission.

Patients with grade 0 and grade 1 esophageal injury were orally fed and discharged 24 h after endoscopy without therapy. Patients with grade 2a were fed with soft cold foods and treated with proton pump inhibitors. Patients with grade 2b and 3 were treated with intravenous antibiotics, proton pump inhibitors, steroids, and parenteral nutrition. Patients with esophageal or gastric lesions were followed-up at 1, 3, and 6 months. Barium meal studies were performed in all patients with grade 2b and 3 esophageal lesions at 4 weeks from ingestion or early if symptomatic and in all patients if symptoms suggestive of esophageal stricture occurred. Esophageal dilations with Savary's dilator were performed if needed.

Statistical analysis was performed among all children who underwent EGD by using the X^2 test or the Fisher exact test, as appropriate. A p-value of ≤0.05 was considered statistically significant and an odds ratio (OR) was calculated with confidence interval (CI) of 95%. A multivariate logistic regression analysis was carried out to identify variables independently associated with an esophageal lesion. Statistical analysis was performed by using the Statistical Package for the Social Sciences (SPSS Inc).

2.1 | Ethics statement

Consent for the study was obtained from all parents or caregivers of children enrolled in the study. The study was approved by the "Cardarelli-Santobono" Independent Ethics Committee and was conducted in accordance with the Declaration of Helsinki and Guidelines for Good Clinical Practice.

TABLE 1 Zargar's classification of caustic esophageal injury.

Grade	Features
Grade 0	No mucosal damage
Grade 1	Superficial mucosal edema and erythema
Grade 2a	Superficial ulcers, erosions, blisters, hemorrhages, or whitish membranes
Grade 2b	Deep or circumferential ulcers
Grade 3a	Focal necrosis, deep gray, or brownish-black ulcers
Grade 3b	Extensive necrosis
Grade 4	Perforation

3 | RESULTS

Over the study period, we enrolled 100 children having ingested bleach (54 males, 46 females; age range 10–198 months; mean age 58.7 ± 54.3 months). Out of them, 5 (5%) were infants, 38 (38%) were toddlers (1–3 years), 27 (27%) were preschool age children (3–5 years), 19 (19%) were school-age children (5–12 years), and 11 (11%) were adolescent (12–18). Forty-three/100 (43%) children were younger than 36 months. Nine patients showed comorbidities: neuropsychiatric disorders ($n = 5$), down syndrome ($n = 1$), autism spectrum disorder ($n = 1$), epilepsy ($n = 1$), and malnutrition ($n = 1$).

At admission 73/100 (73%) patients were symptomatic. The most commonly reported symptoms were vomiting and drooling. The complete list of symptoms is displayed in Table 2.

Eighty/100 (80%) children had ingested commercially available NaOCl-based bleach having a NaOCl concentration of 1%–5%, 9/100 (9%) children had ingested H_2O_2-based bleach and 11/100 (11%) had ingested artisanal or industrial bleaches with a higher or unknown NaOCl or H_2O_2 concentration and not certain overall chemical composition. The mean pH of ingested bleaches, measured or retrieved from product labels, was 12.5.

Ingested bleach was inappropriately stored in glasses or water bottle in 20/100 (20%) cases, thus configuring the so-called "accidental-deliberate" ingestions. Sixty/100 (60%) ingestions were accidental (bleach was ingested from its original container) whereas 13/100 (13%) were intentional with self-injurious or suicidal purposes and the remaining 7/100 (7%) were ambiguous as for the intention of ingestion. The majority of household bleach-related injuries occurred at home (75/100, 75%).

Ingestions are often likely involved small quantities of bleach. Yet, the amount of ingested bleach was always difficult to quantify. Only in four cases, the amount ingested was reported perhaps greater than 100 mL.

TABLE 2 Symptoms reported by the enrolled children.

Symptoms	Number and %
Vomiting	25 (25%)
Drooling	17 (17%)
Pharyngodynia	12 (12%)
Epigastric pain	10 (10%)
Nausea	5 (5%)
Blood vomiting	3 (3%)

Oral cavity lesions such as erythema and ulcers were observed in 12/100 (12%) children. Seven/100 (7%) children presented with respiratory symptoms. Out of them two underwent laryngoscopy evaluation which revealed only mild erythema of the arytenoid folds. No abnormal blood tests were registered.

EGD was performed in 71/100 (71%) patients. Twenty-nine/100 (29%) children were clinically monitored for 6–12 h and underwent a refeeding trial before being discharged. EGD was performed at a mean time of 15.9 ± 5.4 h (range 6–24 h) after bleach ingestion.

Among the 71 children who performed EGD, no children reported severe esophageal lesions. Ten/71 (14%) showed mild esophageal lesions. Of note, Zagar's score 0 was reported in 61/71 (85.9%) children, Zargar's score 1 in 8/71 (11.3%) and Zargar's score 2a in 2/71 (2.8%). Both patients who reported moderate esophageal mucosal lesions (Zargar's grade 2a) had ingested a homemade NaOCl-based bleach with unknown dilution.

Gastric injury was reported in 6/71 (8.5%) patients, including hemorrhagic gastritis in one child. Among these children, five had ingested an artisanal or industrial bleach, and two had ingested a peroxidase-based bleach. Finally, very mild duodenal lesions were reported in 2/61 (3.3%) patients.

All in all, among the 51 children having ingested commercially available household NaOCl bleach who underwent EGD, only 5/51 (9.8%) children were diagnosed with very mild esophageal lesions (Zargar's score 1) (2/5 were accidental-deliberate ingestions, 2/5 were voluntary ingestions and 1/5 was a properly accidental ingestion) whereas the remaining 46/51 (90.2%) did not report any mucosal lesions. Moreover, no gastric mucosal lesions were observed.

All in all, among the nine patients having ingested peroxidase-based bleach, 1/9 (11.1%) was diagnosed with very mild esophageal lesions (Zargar's score 1) whereas 2/9 (22.2%) with gastric mucosal lesions (hemorrhagic gastritis and furrows of gastric fundus).

Finally, among the 11 patients having ingested artisanal or industrial bleaches with a higher or unknown NaOCl or H_2O_2 concentration, esophageal lesions were reported in 4/11 (36.4%) (two Zargar's score 2a and two Zargar's score 1) and gastric lesions were reported in 4/11 (36.4%) (hemorrhagic gastritis and furrows of gastric fundus or body). Different data on esophageal lesion rate according to the different kind of ingested bleach are shown in Figure 1.

Forty-seven/100 (47%) children required hospital admission. Their mean hospital stay was 38.1 ± 33.2 h. Patients with Zargar's score of 0–1 were promptly commenced on oral feeding and discharged home 24 h post-EGD with no treatment. Patients with Zargar's score of 2a were started on a diet based on easily digestible cold foods and received proton pump inhibitors.

At 1-, 3-, and 6-month clinical follow-up all children were asymptomatic. No esophageal stricture occurred.

According to our study data, children having ingested artisanal or industrial bleaches were significantly more likely to experience esophagogastric

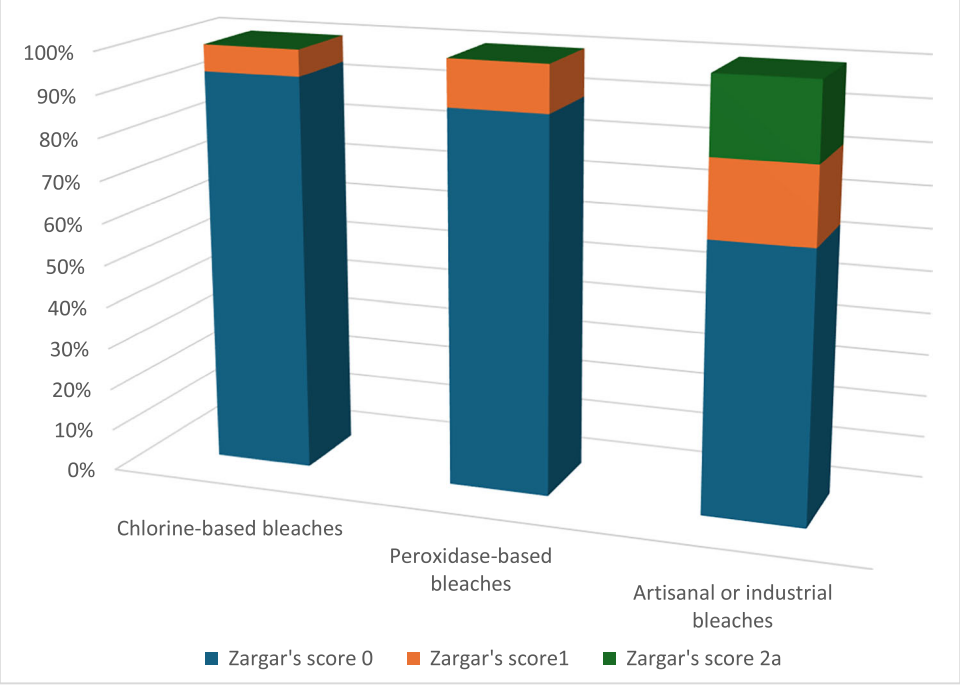

FIGURE 1 Esophageal lesion score according to the different ingested bleach.

lesions compared to children having ingested commercially available household bleaches ($p < 0.01$). Conversely, we didn't find any statistical difference within the outcome of children having ingested NaOCl or peroxidase-based bleach, having both reported mild or no esophagogastric lesion. The only exception concerned the rate of gastric lesions, which was significantly higher for peroxidase-based bleach compared to chlorine-based products ($p < 0.01$).

According to the multivariate logistic regression analysis, no significant statistical differences were found in the rate of esophagogastric mucosal lesions among children with different ingestion modalities: 9/60 (15%) with accidental ingestion, 6/20 (30%) with accidental-deliberate ingestions and 2/13 (15.4%) with voluntary ingestion (p:0.3). Indeed, despite being double the rate of mucosal lesions in children with accidental-deliberate ingestion compared to children with other ingestion modalities, the difference didn't reach statistical significance (p:0.19). No difference in the outcome related to the likely amount of ingested bleach was reported. Finally, the rate of children diagnosed with mucosal lesions were 4/12 (33.3%) among those showing oral cavity lesions and 9/59 (15.3%) among those without oral cavity lesions (p:0.21).

All children who were diagnosed with a variable degree of esophagogastric mucosal lesions showed symptoms after the ingestion (13/13, 100%). However, 60/73 (82.2%) of children showing symptoms at admission had a negative endoscopic evaluation (p:0.02). Symptoms mainly associated with mucosal lesions were epigastric pain (3/10, 30%), vomiting (6/25, 24%), drooling (3/17, 17.6%), and pharyngodynia (2/12, 16.7%).

4 | DISCUSSION

The ingestion of caustic agents may be life threatening according to the type of corrosive substance ingested. Bleach is one of the most frequently ingested substance and its ingestion is a current healthcare issue in pediatric age. Bleach is the popular name for sodium hypochlorite in aqueous solution but is commonly used to indicate overall whitening substances.

The majority of children ingestion involves household bleaches as they are most available and commonly used for cleansing purposes. The main finding of our study is that children having ingested household bleaches did not report any significant esophageal mucosal lesion nor any complications. In our series, we have not found severe esophageal injury (Zargar score IIb-III-IV) nor development of esophageal strictures in these children. This is probably related to the different types of potential tissue damage induced by caustic substances (acids, alkalis, and bleaches) and to the low toxic substance concentrations. Acids induce coagulation necrosis, which limits deep penetration. Acidic substances travel rapidly through the esophagus due to their low viscosity causing mainly gastric injuries. On the contrary, alkalis damage tissue by saponifying fats, resulting in deep penetration of tissue, mainly limited to the esophagus.[1,15] The toxicity mechanism of bleaches is different. When NaClO is dissolved in water, the active form is primarily hypochlorous acid (HOCl), rather than the dissociated hypochlorite ion (OCl-). NaOCl is an oxidizing agent whose potential to cause toxicity is related to its concentration, oxidizing capacity, and pH of the associated solution.[8] Commercial liquid household bleaches in Europe typically have concentrations up to 10% (usually ranging from 1% to 6%) and often contain low concentrations (<0.5%) of sodium hydroxide (Liquid Caustic Soda/NaOH) to maintain a pH-dependent equilibrium between hypochlorite and chlorine.[17] Their pH levels fall within the range of 11–13. Over the last few years, new bleaches have entered the market whose whitening power is not linked to the presence of sodium hypochlorite but of hydrogen peroxide (H_2O_2) diluted at 5%–15%. Nevertheless, according to our data even the ingestion of these peroxidase-based bleach didn't lead to significant esophagogastric mucosal lesions.

As a consequence of our findings, we may suggest a more conservative clinical approach for children for whom it can be established with certainty the ingestion of commercially available household bleach and after checking the concentration of sodium hypochlorite or hydrogen peroxide on the product label. Both kind of bleach products don't seem to be able to cause significant mucosal injuries.

Moreover, we must consider that pediatric ingestions often involve small quantities. Indeed, the exact amount of ingested bleach is difficult to quantify in pediatric cases. Large amounts are very rarely involved and usually related to voluntary ingestions. We reported only four ingestions of more than 100 mL of substance without any difference in the outcome. However, when a large volume ingestion is witnessed or suspected, we believe hospitalization for observation should be recommended and endoscopy performed following symptom onset.

Our findings highlight a slight difference between the corrosive potential of the above-mentioned two kinds of household bleaches. Indeed, peroxidase-based bleach led to gastric mucosal injuries in about one-fifth of cases, compared to no cases reported for chlorine-based bleach. Therefore, it may be reasonable to recommend acid suppressive therapy for children having ingested H_2O_2-containing products, regardless of whether the endoscopic procedure is performed.

On the other hand, our study shows that children having ingested industrial or homemade bleach may seriously suffer mucosal damage. Industrial, homemade,

and household bleaches from other countries may be more corrosive due to potentially higher concentrations of NaOCl (>6%) or H_2O_2 (>10%) and the addition of sodium hydroxide >0.5% to stabilize the solution.[8,12] Therefore, these children deserve a timely endoscopic evaluation and a subsequent targeted therapy.

Secondary findings of our study are that children having ingested bleach were mainly male, and the majority ingested NaOCl-based bleaches, which are more widespread than H_2O_2-based ones. Our experience confirms the findings of a recent meta-analysis showing that overall caustic ingestion is more common among boys and that the most ingested substances in North America and Europe are alkalis, such as chlorine-based bleach.[1,3,5,18–20]

Household cleaning products tend to attract children due to their vibrant colors, pleasant scents, and brightly designed packaging. In our study, the highest percentage of ingestions occurred among toddlers (children aged 1–3 years). This could be related to their developmental phase, featured by strong inclination towards exploration and general curiosity about their surroundings.[3]

In our series, accidentally ingested products were inappropriately stored in glasses or water/juice bottles in 20% of cases. These ingestions led twice as frequently to mucosal damage likely due to the greater amount of the substance ingested, even if the reported difference between "accidental-deliberate" and accidental ingestions did not reach statistical significance. However, these data support an urgent need for specific laws aimed at avoiding the inappropriate storage of caustic products and the role of scientific societies and pediatricians to educate caregivers and public opinion on the possible dramatic consequences of caustic ingestions and that their prevention require only few but very important precautions.[21]

According to our study data, no sign or symptom was able to predict mucosal lesion findings at endoscopy. In our series no children diagnosed with mucosal injuries was asymptomatic at admission. However, this data is weakened by the finding of 82% of symptomatic children who were not diagnosed with mucosal lesions. The predictability of esophageal injury based on signs and symptoms in caustic ingestions and the need for upper gastrointestinal endoscopy has conflicting results in prior studies.[1,10,11,22,23] With regard to this topic, we believe that our study doesn't provide significant insights due to the relatively small sample for this type of analysis.

5 | CONCLUSIONS

Accidental ingestion of bleach by daring children is a current issue whose management is still controversial. Our data suggest that the toxicity of commercially available bleaches (NaOCL-based and H_2O_2-based) on the gastrointestinal tract is very low and comparable to that of other household products generally considered safe. Neither NaOCL-based nor H_2O_2-based marketed bleaches are able to cause esophageal lesions that may require specific therapy. Therefore, digestive endoscopy is generally unnecessary in cases of household bleach ingestion.

Of note, in our series, peroxidase-based bleach led to mild gastric mucosal injuries in about one-fifth of cases. Thus, it could be reasonable to recommend acid suppressive therapy for every child who has ingested H_2O_2-containing products, regardless of whether the endoscopic procedure is performed.

Conversely, a timely endoscopic evaluation and close follow-up should be performed in children who ingest homemade or industrial bleaches, since H_2O_2 and NaOCl concentrations could be much higher and mucosal injuries more likely.

Finally, according to our data, no sign or symptom complained by children is able to predict mucosal lesion findings nor the need for upper gastrointestinal endoscopy.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

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