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Original Article

pH and specific gravity of corrosive agents as indicators in caustic injuries

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Abstract ***Background*:** Video endoscopy, which remains the diagnostic gold standard after ingestion of a corrosive substance, is performed under general anesthesia in children, requires advanced technology, and is costly. Simple and accessible methods are therefore needed to determine the need for endoscopy. The aim of this study was to evaluate the role of the pH and specific gravity of ingested substance in determining endoscopy indications after corrosive ingestion.

***Methods*:** This prospective study included pediatric patients who presented after ingesting a corrosive substance from June 2018 to June 2019. Relationships between the extent of damage detected by endoscopy and the patient's age, physical examination findings, and the pH and specific gravity of the causative substance were evaluated.

***Results*:** The degree of damage detected on endoscopy was significantly milder for corrosive substances with a pH between 2 and 12 ($P = 0.003$). In addition, pH values between 2 and 12 were significantly more common among patients without physical examination findings ($P = 0.029$). Specific gravity less than 1,005 was associated with mild injury detected by video-endoscopy ($P = 0.011$). Patients in whom severe injury was detected by endoscopy had marked findings on physical examination ($P < 0.001$). There was no significant relationship between physical examination findings and the specific gravity of the substance involved ($P = 0.087$).

***Conclusions*:** The results of this study suggest that conservative treatment options can be used without performing endoscopy in patients who have no physical examination finding after corrosive ingestion and where the pH of the substances is between 2 and 12 and the specific gravity of the substances is less than 1,005.

Key words caustic ingestion, endoscopy, esophageal injury, pH, specific gravity.

Despite increased prevention strategies and education efforts, gastrointestinal tract injury due to ingestion of caustic substances is a common health problem, especially in underdeveloped and developing countries.[1] Caustic ingestion is usually accidental in children aged 1–5 and is used as a suicide method in adolescence and adulthood.[2,3] The properties of the ingested substance determine its physiopathologic effect on the gastrointestinal tract.[4] It has been suggested that the severity of damage varies according to the pH, concentration, viscosity, and quantity of the causative agent.[5] Indicators of the clinical course of caustic ingestion include symptoms and physical examination findings, computed tomography findings, and grading based on video endoscopic examination of the upper gastrointestinal tract, which is still the gold standard diagnostic method.[6–10] However, access to this procedure is limited because the gastrointestinal endoscopy system requires advanced technology and a major expenditure during the installation stage, the procedure requires general anesthesia for children, and there are not enough experienced pediatric endoscopists in rural areas. Simple methods are therefore needed to confirm in advance which patients will benefit from endoscopy.

Although there are many studies in the literature about gastrointestinal injuries caused by caustic ingestion, there are no data on the relationship between the pH and specific gravity of the causative agent and endoscopy findings. The aim of the present study was to determine the pH and specific gravity of the causative agents and evaluate the relationship between these parameters and endoscopic findings in patients who presented due to caustic ingestion and were underwent diagnostic endoscopy.

Methods

This prospective study included 46 children who presented after caustic ingestion and were diagnosed and treated in our center between June 2018 and June 2019. Approval for the study was obtained from the Clinical Research Local Ethics Committee of the university in which the study was performed

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(2018/255). The patients and their families were informed about their condition, treatment methods, and the study. Patients whose legal guardians signed an informed consent form and provided the ingested substance upon presentation to the hospital were included in the study. The pH of the causative agent was measured with an electronic pH meter (AD11 pH meter, Adwa Hungary Kft, Szeged, Hungary) and its specific gravity was measured using a reagent strip (Aution sticks, Arkray Factory Inc., Amstelveen, the Netherlands). For technical standardization of measurements, solid causative agents (granule or tablet forms) were excluded from the study. Patients were divided into three groups based on their physical examination findings: patients with no marked physical examination findings (Group 1), patients with mild oropharyngeal and labial hyperemia (Group 2), and patients with excessive hypersalivation, oropharyngeal, lingual, labial pseudomembranes and/or plaques (Group 3). The active substances were classified into three pH groups: pH < 2 (Group A), 2 < pH < 12 (Group B), and pH > 12 (Group C).[9] The reactive strips used to measure specific gravity provide measurement values between 1,005 and 1,030. Specific gravity values outside this range are determined as <1,005 and >1,030 by the specific gravity indicator on the reactive strips.[11] Therefore, the active substances were also divided into three groups according to their specific gravity values: <1,005, 1,005–1,030, and >1,030. All patients underwent upper gastrointestinal endoscopy using a video-endoscope under general anesthesia as a diagnostic procedure after caustic ingestion. The damage detected on endoscopic examination was graded according to the classification defined by Zargar *et al.*[8]

Statistical analyses

Patient data such as age, gender, timing of endoscopy, timing of oral feeding, length of hospital stay, and complications were analyzed using descriptive statistics such as mean, standard deviation, and percentage values. Relationships between endoscopic grades and physical examination findings, age, and the pH and specific gravity of the ingested substance were examined. A χ^2 analysis was used to evaluate the distribution of mean pH and standard deviation values in the endoscopic injury grades. The distribution of specific gravity in the endoscopic injury grades was evaluated using analysis of variance and Tukey's test.

Results

The study included 46 patients, 19 girls (41.3%) and 27 boys (58.7%), who presented to our clinic between June 2018 and June 2019 after caustic ingestion. The mean age was 2.71 ± 1.86 (minimum 1, maximum 11) years. Twenty-one patients who presented for the same reason during the study period but could not supply the ingested substance were excluded from the study. According to the physical examination findings, Group 1 included 17 patients (37%), Group 2 included 13 patients (28.3%), Group 3 included 16 patients (34.8%). It was found that 35 (76.1%) of the causative agents were commercial brand products while 11 (23.9%) were off-brand products. Among causative agents the most common was bleach (n = 11, 23.6%) and the least common was hair bleach (n = 1, 2.1%). Other causative agents ingested by the patients included drain openers, dishwasher detergents and rinse aids, wart removers, surface disinfectants, degreasers, vinegar spirit, and industrial chemicals.

Mean pH of the causative agents measured using an electronic pH meter was 7.44 ± 5.99 (minimum 0.1, maximum 14.1). Twenty-five (54.3%) of the ingested substances were alkaline (pH > 7.4) and 21 (45.7%) were acidic (pH < 7.4). Eleven (23.9%) of the causative agents were in pH group A (pH < 2), 18 (39.1%) were in pH group B (pH 2–12), and 17 (36.9%) were in pH group C (pH > 12). The mean duration of video-endoscopy was 10.32 ± 4.94 h (minimum 2, maximum 24). Severity of caustic injury according to the results of diagnostic endoscopy was Grade 0 in 8 patients (17.4%), Grade 1 in 20 patients (43.5%), Grade 2A in 13 patients (28.3%), and Grade 2B in 5 patients (10.9%). None of the patients in the study had Grade 3–4 caustic injury. Patients in Grade 2A and Grade 2B, which were the most severely affected groups, accounted for 89% of pH group A (pH < 2), 16% of pH group B (2 < pH < 12), and 36% of pH group C (pH > 12).

The mean time to resume oral intake was 31.32 ± 30.72 h (minimum 1, maximum 144) and the mean length of hospital stay was 3.04 ± 2.84 days (minimum 1, maximum 16). No early complications were observed after diagnostic endoscopy in the patients included in the study. At 6 month follow up, esophageal stricture requiring dilation was detected in two patients (4.3%).

The relationship between the acidity or alkalinity of the causative agents and the severity of the resultant esophageal injury was evaluated. The distribution of acids/alkalis was homogenous among the injury grades (P = 0.121) (Table 1). However, the degree of damage detected on endoscopy was significantly milder for corrosive substances with pH between 2 and 12 (P = 0.003; Table 2). In addition, when the relationship between the specific gravity values of the causative agents and the degree of damage detected by esophagoscopy was examined, it was found that specific gravity <1,005 was significantly associated with lower grade of damage detected by video-endoscopy (P = 0.011; Table 3).

Table 1 Relationship between the acidity or alkalinity of the caustic substance ingested by the patients and endoscopic injury grading

	Grade 0 *n* (%)	Grade 1 *n* (%)	Grade 2A *n* (%)	Grade 2B *n* (%)	*P*
Acid (7.4 < pH)	1 (12.5)	9 (45)	8 (61.5)	3 (60)	0.121
Alkali (7.4 > pH)	7 (87.5)	11 (55)	5 (38.5)	2 (40)	

Acids and alkalis were distributed homogeneously among the injury grades (P = 0.121).

Table 2 Relationship between endoscopic injury grade and pH of the ingested caustic substances

		Grade 0 *n* (%)	Grade 1 *n* (%)	Grade 2A *n* (%)	Grade 2B *n* (%)	*P*
pH	<2	1 (12.5)	0 (0)	6 (46.2)	4 (80)	0.003
	2–12[†]	2 (25)	13 (60)	3 (23.1)	0 (0)	
	>12	5 (62.5)	7 (35)	4 (30.8)	1 (20)	

[†]The degree of damage detected on endoscopy was significantly milder for corrosive substances with pH between 2 and 12 ($P = 0.003$).

Table 3 Relationship between the specific gravity of caustic substances ingested and endoscopic injury grade

Specific Gravity	Grade 0 *n* (%)	Grade 1 *n* (%)	Grade 2A *n* (%)	Grade 2B *n* (%)	*P*
<1,005	4 (8.6)	1 (2.1)	1 (2.1)	0	
1,005–1,030	0	3 (6.5)	5 (10.8)	4 (8.6)	0.011[†]
>1,030	4 (8.6)	16 (34.7)	7 (15.2)	1 (2.1)	

[†]Specific gravity <1,005 was significantly associated with the groups with mild damage detected by video-endoscopy ($P = 0.011$).

When the relationship between physical examination findings at time of admission and grade of injury detected by video-endoscopy was examined, it was observed that all patients with severe injury on endoscopy had pronounced findings on physical examination, with a significantly higher proportion of patients in physical examination groups 2 and 3 ($P < 0.001$; Table 4). Evaluation of the relationship between physical examination finding groups and pH groups showed that physical examination finding group 1 (no findings) was significantly associated with pH group B (pH: 2–12; $P = 0.029$; Table 5). In addition, nine patients (50%) were in pH group B (pH: 2–12) of the 18 patients in Group 1 (no finding) and the degree of injury detected by video-endoscopy in these patients was Grade 0 in one patients and Grade 1 in eight patients.

There was no significant relationship between physical examination findings and the specific gravity of the causative substance ($P = 0.087$; Table 5). The age distribution was homogenous, with no statistically significant difference among injury grades ($P > 0.05$).

Discussion

Although video endoscopy is still the gold standard for the management of caustic ingestion, disadvantages of grading esophageal injuries by this method include its invasive nature, high cost, the need for advanced technology, and the lack of availability in all centers. Therefore, for caustic ingestion cases in developing countries, using a low-cost pH meter and reagent strips to measure the pH and specific gravity of the causative agent in addition to a simple physical examination may be beneficial in determining endoscopy indication and treatment strategy.

The volume of material ingested, duration of contact, pH, concentration, and patient age are among the factors that enable the prediction of the severity of the gastrointestinal injuries seen on endoscopy in patients after caustic ingestion.[12,13] It was reported that these factors must be considered when determining the indications for endoscopy in cases of caustic ingestion.[12,13] Cheng *et al*. reported that the risk of severe injury is very low in patients with no physical examination findings after accidental caustic ingestion.[10] However, Gorman *et al*. claimed that clinical findings and the extent of caustic injury may not always be related.[14] In this study, patients with severe injury based on a video-endoscopy had more pronounced physical examination findings and the proportion of patients in Groups 2 and 3 increased significantly ($P < 0.001$). This result supports the view that patients without apparent signs on physical examination have less severe injuries and that these patients can be followed more conservatively.

Chibishev *et al*. suggested that ingested caustic substances with pH values lower than 2 or higher than 12 may be associated with a higher endoscopic injury grade.[9] This finding suggests that the degree of damage detected by endoscopy may be milder in cases where the pH of the caustic substance is in the range of 2–12. In addition, Azrak *et al*. conducted a study on changes in the pH value in saliva secretions after food intake in children and found that the pH value of frequently consumed foods ranged from 2 to 12.[15] For these reasons, the corrosive substances were divided according to pH into three groups: $pH < 2$, $2 < pH < 12$, and $pH > 12$. Our findings corroborate this, as the degree of damage detected on endoscopy was significantly milder for corrosive substances with pH between 2 and 12 ($P = 0.003$). In addition, there was a

Table 4 Relationship between physical examination findings and endoscopic injury grade

		Grade 0 *n* (%)	Grade 1 *n* (%)	Grade 2A *n* (%)	Grade 2B *n* (%)	*P*
Physical examination findings	Group 1: none	5 (62.5)	12 (60)	0 (0)	0 (0)	<0.001[†]
	Group 2: mild oropharyngeal and labial hyperemia	3 (37.5)	8 (40)	2 (15.4)	0 (0)	
	Group 3: hypersalivation, labial, lingual, oropharyngeal plaques and pseudomembrane	0 (0)	0 (0)	11 (84.6)	5 (100)	

[†]Patients with higher endoscopic injury grades had pronounced physical examination findings and the frequency of patients in Groups 2 and 3 increased significantly ($P < 0.001$).

Table 5 Relationship between the physical examination groups and the pH and specific gravity of the corrosive substance

		Physical examination findings			*P*
		Group 1: none *n* (%)	Group 2: mild oropharyngeal and labial hyperemia *n* (%)	Group 3: hypersalivation, labial, lingual, oropharyngeal plaques and pseudomembrane *n* (%)	
pH	<2	0 (0%)	1 (7.6%)	10 (62%)	0.029[†]
	2–12	9 (52.9%)	7 (53.8%)	2 (12.5%)	
	>12	8 (47.1%)	5 (38.4%)	4 (25%)	
Specific gravity	<1,005	2 (11.7%)	3 (23.2%)	1 (6.2%)	0.087[‡]
	1,005–1,030	2 (11.7%)	2 (15.3%)	8 (50%)	
	>1,030	13 (76.4%)	8 (61.5%)	7 (43.7%)	

[†]Physical examination findings in group 1 (no findings) were significantly associated with pH 2–12 ($P = 0.029$).
[‡]There was no significant relationship between physical examination findings and the specific gravity of the causative substance ($P = 0.087$).

significant association between lack of physical examination findings and pH between 2 and 12 ($P = 0.029$). None of the patients who ingested a substance with a pH between 2 and 12 and had no physical examination findings were found to have Grade 2A or Grade 2B damage, which is considered to be severe injury. These results suggest that the pH of the causative agent is a parameter that can be used to predict the degree of damage detected by video-endoscopy, especially in patients without pronounced findings on physical examination.

Hollenbach *et al*. claimed that upper gastrointestinal mucosal damage and associated findings are more common after ingestion of alkalis.[16] However, Taşkınlar *et al*. reported no significant relationship between the acidity or alkalinity of the causative agent and the grade of resulting injury in their study of patients with Grade 2A and Grade 2B esophageal injury after caustic ingestion.[17] In our study, we determined that patients in Grade 2A and Grade 2B, which were the most severely affected groups, accounted for 89% of pH group A ($pH < 2$), 16% of pH group B ($2 < pH < 12$), and 36% of pH group C ($pH > 12$). Moreover, when the distribution of acids and alkalis, which actually have different physiopathologic mechanisms of action, was analyzed based on endoscopic injury grade, we observed a homogeneous distribution of acidic and alkaline agents across the injury severity groups ($P = 0.121$). This result is consistent with the view that the main factor influencing the extent of damage is not whether the ingested substance is acidic or alkaline, but rather whether it is a strong acid ($pH < 2$) or alkali ($pH > 12$).

In terms of the phase of the ingested substance in cases of caustic ingestion, it has been reported that solids cause greater upper gastrointestinal system damage than liquids.[18–20] Due the technical measurement standardization of specific gravity and pH, solid form caustic agents were excluded from the study. Based on a review of the literature on caustic ingestion, it seems that no studies have evaluated specific gravity, which is the polyionic particle density of a substance compared to water as a reference, determined using reactive strips.[19–22] Higher densities of ionic substances such as sodium, potassium, hydrogen, chlorine, and hydrogen peroxide, which are determinants of specific gravity values that can be measured with reactive strips, may have an irritant effect on the epithelium.[23] This suggests that the specific gravity levels of the corrosive substance may affect the degree of damage detected by endoscopy in cases of caustic ingestion. There was no significant difference in the distribution of specific gravity levels of the corrosive substances in the physical examination groups ($P = 0.087$). However, our evaluation of the relationship between the specific gravity of the causative agent and the degree of damage detected by endoscopy indicated that specific gravity less than 1,005 was significantly associated with video-endoscopic findings of mild damage ($P = 0.011$). This suggests that the specific gravity of the causative agent is a parameter that can be used to predict caustic injury severity.

Chirica *et al*. suggested that a larger amount of ingested caustic substance may be related to the severity of intestinal tract damage.[12] On the other hand, Cheng *et al*. reported that they could detect no clear relationship between the amount of substance ingested, which is frequently questioned before endoscopy, and the severity of endoscopic findings.[10] However, Hollenbach *et al*. suggested that the causes of ingestion and the volume of ingested material may vary according to patient age. Adults usually ingest a larger volume than children, which may result in more damage to the gastrointestinal tract.[16] In this study, there was no statistical significance between age and endoscopic injury severity ($P > 0.05$). We also attempted to collect information about the ingested volume during data collection. However, in clinical practice, it was not possible to collect data on this subject in a standardizable way. Most of the time, the children ingested the substance while their parents were not looking and were found holding the bottle, and parents usually report that they ingested a "small" amount. Moreover, although 76.1% of the corrosive substances that the patients came into contact with were commercial products, these products were very diverse and did not have a standard formula. It was also determined that some of the corrosive substances were not in their original packaging but were in a different container, usually in a diluted form for daily use. Therefore, the pH and the specific gravities of the corrosive substances were reanalyzed for each patient in the study.

In patients who ingest caustic substances, endoscopic grading of the resultant injury remains the gold standard in diagnosis. Consistent with this, performing endoscopy as a diagnostic method on patients presenting due to caustic ingestion appears to be a common clinical practice.[10,13,24] However, Gupta *et al*. suggested that endoscopy may not be necessary, especially in patients with no clinical findings.[25] In children presenting after caustic substance ingestion with no pronounced findings on physical examination, we believe that more parameters should be considered when determining indications for endoscopy, which is an invasive diagnostic method often performed under general anesthesia and in operating-room conditions. The findings of the present study support that analyzing the pH and the specific gravity without endoscopy can be preferred conservative treatment method for patients who have no physical examination findings after caustic ingestion.

Different practices regarding treatment management in caustic ingestion have led to the discussion and comparison of the costs associated with these practices. Abbas *et al*. determined a high cost rate of 56% in the diagnosis and treatment process, especially in the group with mild clinical findings.[26] Considering the procedure and consumable materials costs determined by the Ministry of Health in public hospitals during the study period, the cost of endoscopy under general anesthesia in patients presenting due to caustic ingestion was $72.29. Moreover, it was found that the cost of the electronic pH meter used in the study, which has a lifespan of 2–3 years, was $36.58 and the cost of single-use reagent strip was $0.12. As caustic ingestion is a common health problem in underdeveloped and developing countries, the cost of diagnostic procedures and treatment must also be taken into account.

A limitation of this study is that the lack of patients with endoscopic Grade 3–4 esophageal injury and the clinical findings associated with these grades reduces the power of our results. Another issue to consider is the low precision of measurements performed using reagent strips.[27] Finally, the limited number of subjects must also be taken into account when evaluating the results. These results should therefore be corroborated by multi-center studies with larger samples.

In conclusion, low-cost pH and specific gravity measurements of the causative agent may be helpful in determining indications for endoscopy in cases of caustic ingestion in children. Conservative treatment without video-endoscopy may be an option in patients who have no signs of damage on physical examination and who ingested a corrosive substance with a pH between 2 and 12 and specific gravity lower than 1,005.

Disclosure

The authors declare no conflict of interest.

Author contributions

C.İ. designed the data-collection instruments, drafted the initial manuscript, and carried out the initial analysis. C.İ. and İ.K. carried out the initial analysis and reviewed and revised the manuscript. H.T. and A.N. coordinated and supervised data collection and reviewed and revised the manuscript. All authors read and approved the final manuscript.

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