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ORIGINAL SCIENTIFIC REPORT

The Damage Pattern to the Gastrointestinal Tract Depends on the Nature of the Ingested Caustic Agent

Romain Ducoudray[1] · Antoine Mariani[1] · Helene Corte[1] · Aurore Kraemer[1] · Nicolas Munoz-Bongrand[1] · Emile Sarfati[1] · Pierre Cattan[1] · Mircea Chirica[1]

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Abstract

Background The mechanisms of damage to the gastrointestinal tract after caustic ingestion are conditioned by the nature of the ingested agent. Whether the nature of the ingested agent has a direct influence on patient outcomes is unknown.

Methods From January 2013 to April 2015, 144 patients underwent emergency management for caustic injuries at the Saint Louis Hospital in Paris. There were 51 men (51 %) and the median age was 44 years [39, 48]. The ingested agents were soda-based strong alkali in 85 patients (59 %), strong acids in 36 patients (25 %), and bleach in 23 patients (16 %). Emergency and long-term outcomes were compared according to the nature of the ingested agent.

Results Four patients died (3 %) and 40 patients (28 %) experienced complications. After bleach ingestion, emergency morbidity and mortality were nil, no patient required esophageal reconstruction, and functional outcome was successful in all patients. Acids were more likely to induce transmural gastric (31 vs. 13 %, p =0.042) and duodenal (9 vs. 0 %, $p = 0.04$) necrosis than strong alkalis, but rates of transmural esophageal necrosis were similar (14 vs. 12 %, $p = 0.98$). No significant differences were recorded between emergency mortality (9 vs. 1 %, $p = 0.15$), morbidity (33 vs. 33 %, $p = 0.92$), the need for esophageal reconstruction (25 vs. 20 %, $p = 0.88$), and functional success rates (76 vs. 84 %, $p = 0.31$) after acid and alkali ingestion, respectively.

Conclusion Bleach causes mild gastrointestinal injuries, while the ingestion of strong acids and alkalis may result in severe complications and death. Acids cause more severe damage to the stomach but similar damage to the esophagus when compared to alkalis.

Introduction

In adults, caustic ingestion is mostly performed with suicidal purpose and the severity of digestive injuries depends on the nature, the form (liquid vs. solid), the quantity, and the concentration of the corrosive agent [1]. Ingested products are classified as strong corrosive agents, as strong acids and alkalis, and oxidative agents (i.e., bleach). Strong acids have been reported to produce coagulation necrosis which lessens tissue penetration and decreases damage when compared to alkalis which produce liquefaction necrosis resulting in immediate severe injuries at all levels of the gastrointestinal tract [1–4]. The pattern of ingestion varies geographically and is usually conditioned by local customs and the availability of a particular substance. Acids were more frequently ingested in India [5] and Turkey [6], while bleach was the leading cause in the United States [2] and alkalis in Brazil [7], Serbia [8], and France [9].

✉ Mircea Chirica
mirceaxx@yahoo.com; mircea.chirica@sls.aphp.fr

[1] Department of General, Endocrine and Digestive Surgery, Saint-Louis Hospital, APHP, Université Paris 7 Diderot, Paris, France

It has been postulated that acids produce less severe damage of the esophagus than alkalis and tend to affect more often the stomach [1–4]. However, data that address specifically the question are scarce in literature [10, 11] and it remains unclear whether the nature of the ingested agent influences patient outcomes.

The aim of the present study was to assess patterns of damage caused by different corrosive agents on the gastrointestinal tract and to evaluate relationships between the nature of the ingested agent and patient outcomes.

Patients and methods

All consecutive adults (>16 years) referred for emergency management of caustic injuries at the Saint Louis Hospital in Paris between January 1, 2013 and April 30, 2015 were prospectively included.

Emergency management

A new emergency management protocol which included routine CT scan was used during the study period [12]. Briefly, clinically stable patients without signs of gastrointestinal perforation underwent emergent endoscopy 3–6 h after ingestion and injuries were graded according to Zargar et al. [10]. CT examination was performed immediately after endoscopy according to the previously described protocol [12] and was read by the radiologist on call. Patients were offered surgery if endoscopy and CT findings suggested transmural necrosis of the esophagus and/or the stomach. On endoscopy, necrosis was defined as grade 3b injuries of the esophagus and/or the stomach. Radiological signs of transmural necrosis included esophageal-wall blurring on unenhanced images, periesophageal-fat blurring on unenhanced images, and the absence of post-contrast enhancement of the esophageal/gastric wall [12]. Non-operative management was attempted if CT and endoscopy showed discordant findings or concurred in showing the absence of necrosis (Fig. 1).

Esophagectomy was performed when CT and endoscopy indicated esophageal necrosis. Fiberoptic bronchoscopy was systematically performed before esophagectomy and concomitant airway injuries were managed by construction of a pulmonary patch [13]. Suspicion of gastric necrosis led to explorative laparotomy, and resection of the stomach and other abdominal organs was performed only if full-thickness wall necrosis was confirmed by laparotomy [9]. Otherwise, a feeding jejunostomy was done. The surgical specimens were opened and fixed in formalin, and samples were taken at the sites of maximal gross necrosis in the esophagus and the stomach. Microscopic examination evaluated the presence and the depth of intramural necrosis

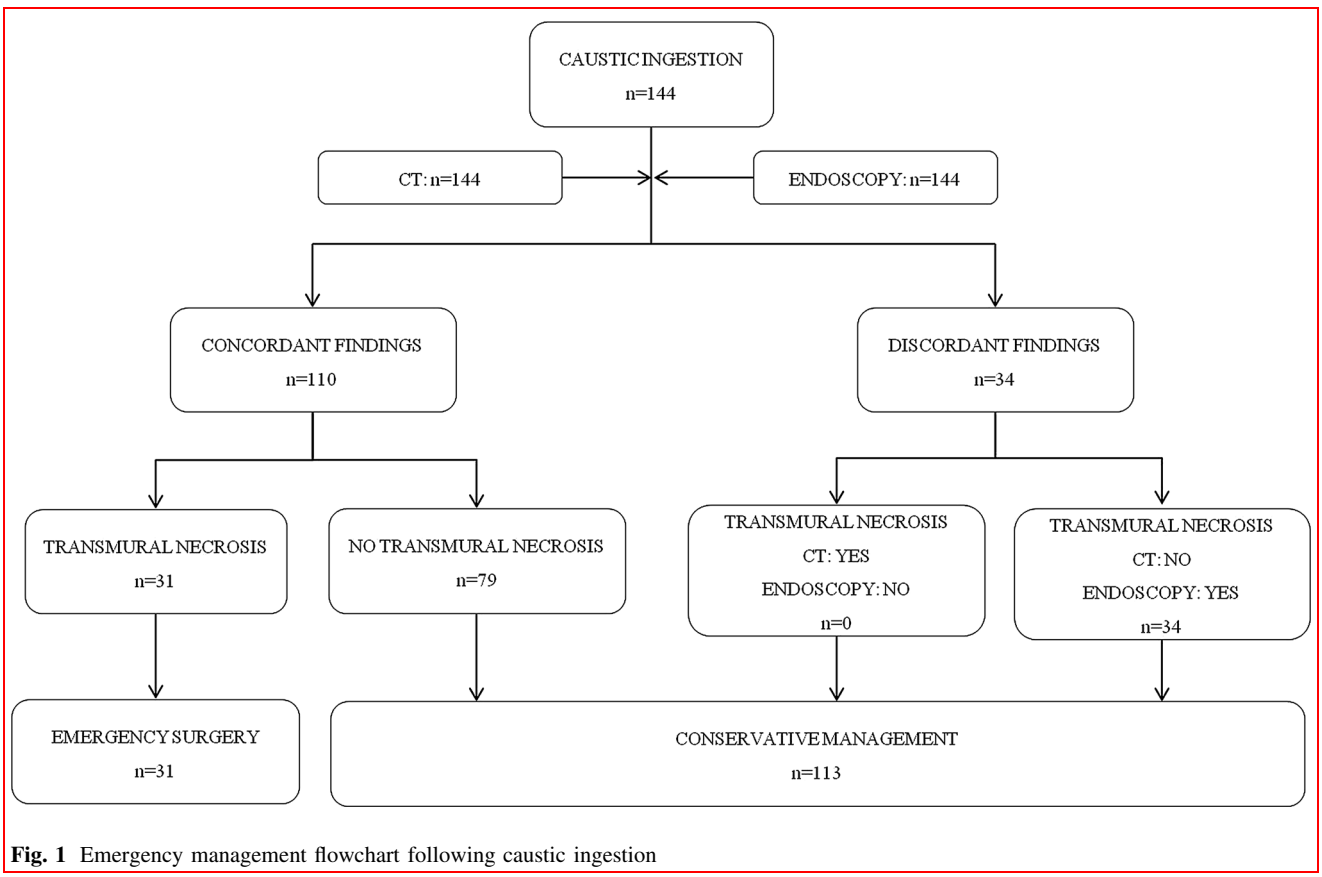

Fig. 1 Emergency management flowchart following caustic ingestion

relying on specific criteria for coagulation necrosis (preservation of the general tissue architecture, preservation of the basic outline of the coagulated cells, marked cytoplasmic eosinophilia with a glassy homogeneous appearance, complete karyolysis producing anucleate cells) and on nonspecific criteria for advanced necrosis (disruption of parietal architecture, necrotic debris inflammatory infiltrate). The presence of both specific and advanced criteria was required to establish the diagnosis of necrosis in any layer, and transmural necrosis was defined as necrosis extending to the external muscular layer of the esophagus and the gastric serosa [12] (Fig. 2).

In case of non-operative initial treatment, oral nutrition was started as soon as patients were in condition to swallow. Esophageal strictures were managed by first-line endoscopic dilation and intractable strictures by esophageal reconstruction [14]. Reconstruction was only considered in psychologically stable patients, at least 6 months after ingestion. Follow-up was conducted as described previously [14]. Functional outcome was considered successful if patients were on exclusive oral diet, and the tracheotomy and jejunostomy tubes have been removed.

Statistical analysis

Results are expressed as median and first and third quartiles [*Q1–Q3*] or counts and percent. Continuous variables were compared using the Mann–Whitney U tests and Fisher's exact, test was used for comparisons of categorical variables. The values of $p \leq 0.05$ were considered statistically significant.

Results

We included 144 consecutive patients who underwent emergency management of caustic ingestion during the study period. There were 51 men (51 %) and the median age was 44 years [39, 48]. Ingestion was suicidal in 129 patients (90 %) of whom 21 patients (15 %) had previous suicide attempts. Sixty four patients (44 %) had a psychiatric history of schizophrenia ($n = 14$) and depression ($n = 50$). The ingested agents were soda-based strong alkali in 85 patients (59 %), strong acids in 36 patients (25 %), and bleach in 23 patients (16 %).

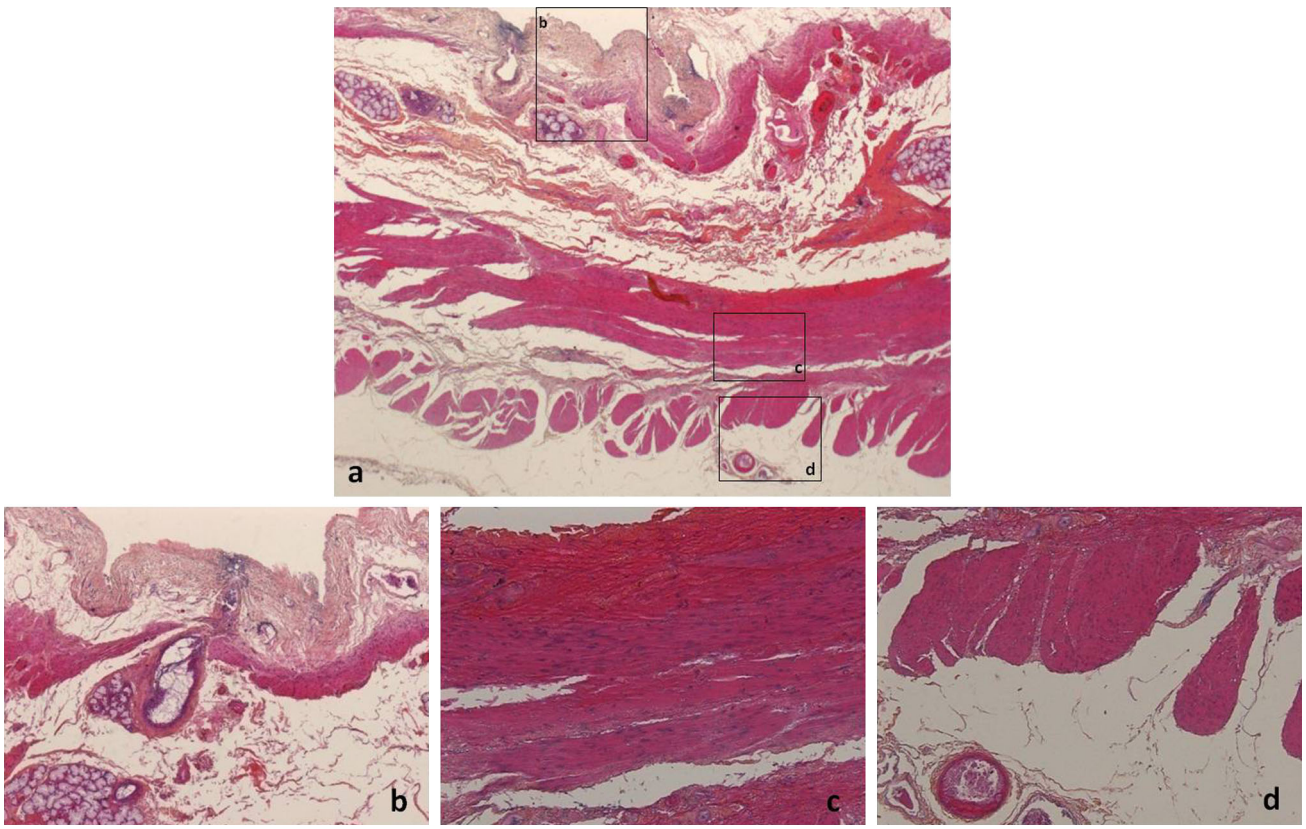

Fig. 2 Hematoxylin and eosin staining section showing massive transmural coagulation necrosis of the esophagus (**a**). Snapshots showing: (**b**) complete coagulation necrosis of the mucosa, partial necrosis of the muscularis mucosa and of the submucosa (persistent submucosal esophageal glands); (**c**) necrosis of the inner muscular layer with mononuclear inflammatory infiltrate and hemorrhagic suffusions; and (**d**) progressive lysis of smooth muscle cells in the outer muscular layer

Ingestion of strong corrosive agents

Strong corrosive agents were ingested by 121 patients (acid $n = 36$, alkali: $n = 85$).There were no significant differences in baseline characteristics between patients who ingested acids and alkalis (Table 1).

Evaluation of caustic injuries of the upper gastrointestinal tract

Endoscopic necrosis (grade 3b) of the esophagus was recorded in 13 patients (36 %) and 35 patients (41 %) after acid and alkali ingestion, respectively ($p = 0.75$). Endoscopic necrosis (grade 3b) of the stomach was recorded in 18 patients (50 %) and 33 patients (39 %) after acid and alkali ingestion, respectively ($p = 0.35$).

CT scan suggested the presence of transmural esophageal necrosis in 5 patients (14 %) and in 11 patients (13 %) after acid and alkali ingestion, respectively ($p = 0.68$). Similarly, CT scan suggested the presence of transmural gastric necrosis in 11 patients (31 %) and in 17 patients (20 %) after acid and alkali ingestion, respectively ($p = 0.31$).

The incidence of oropharyngeal burns was similar after acid (36 %) and alkali (39 %) ingestion ($p = 1$).

Laboratory data

Blood pH values were decreased after acid ingestion (median: 7.37 [7.24, 7.40] vs. 7.40 [7.37, 7.42], $p = 0.002$). Serum values of liver transaminases AST (median: 24 [20, 40] vs. 21 [16, 29], $p = 0.04$) and ALT (median: 26 [16, 45] vs. 19 [13, 28], $p = 0.009$) were also increased after acid ingestion. The nature of the ingested agent had no influence on the serum levels of leucocytes, creatinine, and bilirubin (Table 1).

Table 1 Baseline characteristics of patients with caustic injuries after ingestion of acids ($n = 36$) and strong alkalis ($n = 85$)

	Acid ingestion ($n = 36$) *N* (%)	Alkali ingestion ($n = 85$) *N* (%)	*p*
Age	44 [33,54]	45 [33,58]	0.80
Men	22 (61)	43 (51)	0.32
Psychiatric disease	19 (53)	36 (42)	0.32
Suicide	32 (89)	76 (89)	1
Endoscopic esophageal necrosis (grade 3b)	13 (36)	35 (41)	0.68
Endoscopic gastric necrosis (grade 3b)	18 (50)	33 (39)	0.31
CT esophageal necrosis	5 (14)	11(13)	1
CT gastric necrosis	11 (31)	17 (20)	0.24
pH	7.37 [7.24, 7.40]	7.40 [7.37, 7.42]	0.002
Serum lactates	1.6 [1.1, 2.5]	1.4 [1.05, 2.95]	0.89
ALT	26 [16,45]	19 [13,28]	0.009
AST	24 [20,40]	21 [16,29]	0.04
Bilirubin	10 [6, 13]	9 [6, 14]	0.80
Creatinine	69 [57,84]	66 [54,75]	0.13

The data are *n* (%) or median [interquartile range]

Emergency management

Emergency surgery was performed in 11 patients (31 %) after acid ingestion and in 20 patients (24 %) after alkali ingestion ($p = 0.50$). Esophageal resection rates were similar after acid ($n = 5$; 14 %) and alkali ($n = 11$; 13 %) ingestion ($p = 1$). Gastrectomy was undertaken more frequently after acid ($n = 10$; 28 %) when compared to alkali ($n = 11$; 13 %) ingestion ($p = 0.036$). Another significant difference in operative management was that all 3 pancreatoduodenectomy procedures were performed in the acid ingestion group (9 vs. 0 %, $p = 0.024$). One patient had extensive tracheobronchial necrosis after acid ingestion which was beyond therapeutic resources. Mortality was higher after acid ($n = 3$; 9 %) when compared to alkali ($n = 1$; 1 %) ingestion but figures did not reach significance ($p = 0.15$). Complications were recorded in 12 patients (33 %) and 28 patients (33 %) after acid and alkali ingestion, respectively ($p = 0.83$). Twenty seven (75 %) and 60 patients (70 %) required ICU management after acid and alkali ingestion, respectively ($p = 0.82$). Median hospital stay was 10 [5, 20] days after acid ingestion and 12 [4, 26] days after alkali ingestion ($p = 0.56$; Table 2).

Pathological analysis revealed transmural necrosis in all gastrectomy specimens and in all but one esophagectomy specimen. There was no difference in macroscopic and microscopic characteristics of acid- versus alkali-induced transmural necrosis.

Late outcomes

Of 105 survivors in whom the native esophagus was preserved, 33 patients (31 %) developed esophageal strictures. The rates of esophageal stricture formation were 23 % (7/31) and 35 % (26/74) after acid and alkali ingestion, respectively ($p = 0.30$). Six (86 %) of 7 acid-related esophageal strictures and 13 (50 %) of 26 alkali-related strictures failed endoscopic treatment and required esophageal reconstruction ($p = 0.2$).

Esophageal reconstruction was performed eventually in 9 patients (25 %) after acid ingestion and in 24 patients (28 %) after alkali ingestion ($p = 0.82$). Alimentary reconstruction could not be performed in one patient because of failure to control the psychiatric disease. Sixteen patients developed pharyngeal strictures requiring

Table 2 Management and outcomes of patients with caustic injuries after ingestion of acids ($n = 36$) and strong alkalis ($n = 85$)

	Acid ingestion ($n = 36$) *N* (%)	Alkali ingestion ($n = 85$) *N* (%)	*p*
Emergency surgery	11 (31)	20 (24)	0.50
Esophagogastrectomy	5	8	
Esophagectomy	0	3	
Total gastrectomy	5	3	
Laparotomy–jejunostomy	1	6	
Emergency PD	3	0	0.024
Emergency mortality	3 (9)	1(1)	0.08
Emergency morbidity	12 (33)	28 (33)	0.83
Tracheotomy	5 (14)	10 (12)	0.77
ICU management	27 (75)	60 (70)	0.83
Hospital stay	10 [5, 20]	12 [4, 26]	0.56
Esophageal reconstruction[a]	9 (25)	24 (28)	0.83
Functional success[a]	25 (75)	72 (86)	0.27

The data are *n* (%) or median [interquartile range]

PD pancreatoduodenectomy, *ICU* intensive care unit

[a] Evaluated in patients who survived the emergency period

reconstruction by colopharyngoplasty [15] with no significant difference between acid ($n = 7$) and alkali ($n = 9$) ingestion ($p = 0.14$). Mortality after esophageal reconstruction was nil. The nature of the ingested caustic agent had no influence on early ($p = 0.7$) or late morbidity ($p = 0.31$) after esophageal reconstruction.

Median follow-up was 10 months [5, 14] and no patient was lost to follow up. Functional success was recorded in 76 and 84 % of patients after acid and alkali ingestion, respectively ($p = 0.27$). No patient attempted re-suicide.

Ingestion of bleach

Twenty three patients (16 %) consulted after ingestion of household bleach.

Endoscopy revealed severe esophageal injuries (grade 3) in 2 patients (9 %) of whom one had grade 3b necrosis. Severe gastric burns (grade 3) were recorded in 6 patients (26 %) of whom 2 were graded 3b. CT scan findings showed the absence of transmural esophageal and gastric necrosis in all patients. All 23 patients underwent successful non-operative management. Mortality and in-hospital morbidity after bleach ingestion were nil and no patient required intensive care unit (ICU) management. Median in-hospital stay was 3 days [2, 8]. Two patients (9 %) with grade 2b and grade 3b esophagitis developed esophageal strictures 90 days and 45 days after ingestion, respectively. They are both symptom free 1 year after the first session of endoscopic dilation. After a median follow-up of 8 months [4, 12], all patients were alive and had a successful functional outcome.

Discussion

The present study reports on 144 consecutive patients managed for caustic injuries focusing on the specific issue of the ingested agent nature influence on the damage pattern to the gastrointestinal tract. Publications addressing the question are scarce in the literature and results are conflicting [1, 2]. Findings of this study offer new insights on gastrointestinal damage patterns caused by various corrosive agents, with useful implications on clinical management.

It has been postulated that acids "lick the esophagus and bite the stomach" [3]. The results of the present study contradict the first part of the statement and endorse the second. Actually, damage to the esophagus was similar after both acid and alkali ingestion. There was no significant difference between rates of transmural esophageal necrosis, esophageal stricture formation, failure of endoscopic management of esophageal strictures, and need for esophageal reconstruction. Our data suggest that acids do not spare the esophagus. In contrast, explorative laparotomy and pathologic analysis of operative specimens revealed that acid ingestion induced more severe damage to the stomach when compared to alkalis. We also recorded a significantly higher incidence of pathologically proven full-thickness duodenal wall necrosis after acid ingestion. This finding is in accordance with the high proportion of acid ingestion reported by our group after pancreatoduodenectomy for caustic injuries [16]. Of note, the incidence of early oropharyngeal burns and of pharyngeal strictures was similar after ingestion of acids and alkalis; occurrence of pharyngeal injuries is most likely to be conditioned by the pattern of ingestion (hesitation before swallowing, provoked vomiting) rather than the nature of the ingested agent [15]. Acid ingestion induced systemic (acidosis) and metabolic (liver dysfunction) changes that did not occur after ingestion of either alkalis or bleach. These results are in accordance with other reports in the literature [1, 11]. Mechanisms of tissue damage after acid and alkali ingestion are different. Acids cause coagulation necrosis and eschar formation which limits further tissue penetration, while alkalis combine with tissue proteins, cause liquefactive necrosis and saponification, and penetrate deeper into tissues because of higher viscosity and longer contact time through the esophagus [1, 2]. Accordingly, alkali ingestion may lead to more serious esophageal injuries; pyloric spasm after acid ingestion increases exposure time of this material to the stomach leading to more severe gastric involvement. However, such distinction was not

clinically relevant in the present study probably due to the suicidal intent pattern in the majority of patients. Committing suicide results in high quantities of caustic ingestion and enables rapid tissue penetration and full-thickness damage of the esophageal/gastric wall, regardless of the ingested agent nature (acid /alkali).

Despite these differences, clinical patient outcomes did not seem influenced by the acid or alkaline nature of the ingested agent. Emergency mortality rates were slightly increased after acid ingestion, but the number of events was small and does not allow driving definitive conclusions. The need for extended resections, the rates of pulmonary complications requiring tracheotomy, the overall emergency morbidity, the need for ICU management, and the lengths of hospital stay were similar after acid and alkali ingestion. No differences were recorded in rates of esophageal reconstruction, pharyngeal reconstruction, and the operative outcomes of the reconstruction operation. On summary, despite different patterns of damage inflicted to the upper digestive tract the nature of the ingested agent did not influence global patient outcomes. These results are in contrast with those reported by Poley et al. [11], who reported more severe mucosal injuries, longer hospital stay, increased need for intensive care unit management, and higher rates of systemic complications, perforation, and mortality after acid ingestion. The differences are probably due to the fact that the majority of patients in the Poley et al.'s [11] study had ingested glacial acetic acid; similar to most reports in the literature, patients in the present study had ingested more common acids (sulfuric, hydrochloric). Severe systemic complications are uncommon after ingestion of usual acids, but have been frequently described after the ingestion of glacial acetic acid [17, 18] and may explain for the increased mortality.

Bleach ingestion warrants further discussion. Bleach is readily sold over counter in France as household cleansing agents, and stood for 16 % of corrosive ingestions in the present study. Damage to the gastrointestinal tract was mild in all patients. The outcome was favorable in all cases without need for emergency or reconstructive surgery. This findings support existing data [1, 2] in the literature and should be kept in mind during emergency management of caustic injuries; in doubtful situations, conservative management should be attempted first if bleach was involved, even if resective surgery has been reported after bleach ingestion [9].

The main study shortcoming was the inability to assess other factors that determine the pattern of gastrointestinal injuries and affect directly patient outcomes such as the concentration and the quantity of the ingested agent could not be evaluated. Unfortunately, the problem can be hardly overcome because a reliable evaluation of these parameters in the emergency setting is often impossible [1–4].

In conclusion, the nature of the ingested agent conditions the pattern of gastrointestinal damage and the outcomes of patients with caustic injuries. Bleach ingestion results in mild gastrointestinal injuries and favorable outcomes, while the ingestion of strong acids and alkalis induces more severe injuries that may lead to complications and death. Acids cause more severe damage to the stomach when compared to alkalis, but this difference has no specific influence on patient outcomes.

Compliance with ethical standards

Conflict of interest Drs. Romain Ducoudray, Antoine Mariani, Helene Corte, Aurore Kraemer, Nicolas Munoz-Bongrand, Emile Sarfati, Pierre Cattan, and Mircea Chirica have no conflicts of interest or financial ties to disclose.

References

1. Contini S, Scarpignato C (2013) Caustic injury of the upper gastrointestinal tract: a comprehensive review. World J Gastroenterol 19:3918–3930
2. Hugh TB, Kelly MD (1999) Corrosive ingestion and the surgeon. J Am Coll Surg 189:508–522
3. Keh SM, Onyekwelu N, McManus K, McGuigan J (2006) Corrosive injury to upper gastrointestinal tract: still a major surgical dilemma. World J Gastroenterol 12:5223–5228
4. Ramasamy K, Gumaste VV (2003) Corrosive ingestion in adults. J Clin Gastroenterol 37:119–124
5. Zargar SA, Kochhar R, Mehta S, Mehta SK (1991) The role of fiberoptic endoscopy in the management of corrosive ingestion and modified endoscopic classification of burns. Gastrointest Endosc 37:165–169
6. Ertekin C, Alimoglu O, Akyildiz H, Guloglu R, Taviloglu K (2004) The results of caustic ingestions. Hepatogastroenterology 51:1397–1400
7. Mamede RC, de Mello Filho FV (2001) Ingestion of caustic substances and its complications. Sao Paulo Med J 119:10–15
8. Knezevic JD, Radovanovic NS, Simic AP, Kotarac MM, Skrobic OM, Konstantinovic VD, Pesko PM (2007) Colon interposition in the treatment of esophageal caustic strictures: 40 years of experience. Dis Esophagus 20:530–534
9. Chirica M, Resche-Rigon M, Bongrand NM, Zohar S, Halimi B, Gornet JM, Sarfati E, Cattan P (2012) Surgery for caustic injuries of the upper gastrointestinal tract. Ann Surg 256:994–1001
10. Zargar SA, Kochhar R, Nagi B, Mehta S, Mehta SK (1989) Ingestion of corrosive acids. Spectrum of injury to upper gastrointestinal tract and natural history. Gastroenterology 97:702–707
11. Poley JW, Steyerberg EW, Kuipers EJ, Dees J, Hartmans R, Tilanus HW, Siersema PD (2004) Ingestion of acid and alkaline agents: outcome and prognostic value of early upper endoscopy. Gastrointest Endosc 60:372–377
12. Chirica M, Resche-Rigon M, Pariente B, Fieux F, Sabatier F, Loiseaux F, Munoz-Bongrand N, Gornet JM, Brette MD, Sarfati E, Azoulay E, Zagdanski AM, Cattan P (2015) Computed tomography evaluation of high-grade esophageal necrosis after corrosive ingestion to avoid unnecessary esophagectomy. Surg Endosc 29:1452–1461
13. Benjamin B, Agueb R, Vuarnesson H, Tranchart H, Bongrand NM, Sarfati E, Cattan P, Chirica M (2015) Tracheobronchial necrosis after caustic ingestion. Ann Surg. doi:10.1097/SLA.0000000000001188

14. Chirica M, Veyrie N, Munoz-Bongrand N, Zohar S, Halimi B, Celerier M, Cattan P, Sarfati E (2010) Late morbidity after colon interposition for corrosive esophageal injury: risk factors, management, and outcome. A 20-years experience. Ann Surg 252:271–280
15. Chirica M, de Chaisemartin C, Goasguen N, Munoz-Bongrand N, Zohar S, Cattan P, Brette MD, Sarfati E (2007) Colopharyngoplasty for the treatment of severe pharyngoesophageal caustic injuries: an audit of 58 patients. Ann Surg 246:721–727
16. Lefrancois M, Gaujoux S, Resche-Rigon M, Chirica M, Munoz-Bongrand N, Sarfati E, Cattan P (2011) Oesophagogastrectomy and pancreatoduodenectomy for caustic injury. Br J Surg 98:983–990
17. Kamijo Y, Soma K, Iwabuchi K, Ohwada T (2000) Massive noninflammatory periportal liver necrosis following concentrated acetic acid ingestion. Arch Pathol Lab Med 124:127–129
18. de Vries RR, Sitalsing AD, Schipperheyn JJ, Sedney MI (1977) Clinical aspects of acetic acid poisoning. Ned Tijdschr Geneeskd 121:862–866