Alkalis - draft revised Poisons Information Monograph for peer review

Alkalis

International Programme on Chemical Safety
Poisons Information Monograph G012 (Group PIM)
Chemical

1. NAME

1.1 Substance

Alkalis

1.2 Group

Substances included:

Sodium hydroxide
Potassium hydroxide
Calcium hydroxide

1.3 Synonyms

Sodium hydroxide;
Caustic flake;
Caustic soda;
Hydroxyde de sodium (French);
Hydroxyde de sodium, solide (French);
Hydroxyde de sodium, solutions (French);
Lewis-red devil lye;
Liquid caustic (solutions of 45-75% sodium hydroxide in water);
Lye;
Natriumhydroxid (German);
Natriumhydroxyde (Dutch);
Soda lye;
Soda, caustic;
Soda, hydrate;
Sodio (idrossido di);
Sodium hydrate;
White caustic;
Potassium hydroxide
Caustic potash;
Caustic potash solutions;
Hydroxyde de potassium (French);
Hydroxyde de potassium, solide (French);
Hydroxyde de potassium, solutions (French);
Kaliumhydroxid (German);
Kaliumhydroxyde (Dutch);
KOH;
Lye;
Potassa;
Potasse caustique;
Potassio (idrossido di);
Potassium (hydroxyde de);
Potassium hydrate;
Potassium hydrate solutions;
Calcium hydroxide ;
Agricultural lime;
Bell mine;
Biocalc;
Calcium dihydroxide;
Calcium Hydrate;
Calvit;
Calvital;
Carboxide;
Caustic lime;
Caustic lime water;
Hydrated lime;
Hydroxyde de calcium;

Kalkhydrate;
Kemikal;
Limbux;
Lime hydrate;
Lime milk;
Lime water;
Milk of lime;
Slaked lime

1.4 Identification numbers

1.4.1 CAS number

Sodium hydroxide: 1310-73-2
Potassium hydroxide: 1310-58-3
Calcium hydroxide: 1305-62-0

1.4.2 Other numbers

Sodium hydroxide, solid: UN1823 (DOT)
Sodium hydroxide, solution: UN1824 (DOT)
Sodium hydroxide NIOSH/RTECS: WB4900000

Potassium hydroxide, solid: UN1813 (DOT)
Potassium hydroxide, solution: UN1814 (DOT)
Potassium hydroxide NIOSH/RTECS: TT2100000

Calcium hydroxide NIOSH/RTECS: EW2800000

1.5 Main brand names, main trade names

Trade names differ from country to country as there are many combination products.

1.6 Main manufacturers, main importers

There are many manufacturers are importers.

2. SUMMARY

2.1 Main risks and target organs

Alkalis are one of the most common causes of chemical burn. On ingestion alkalis are capable of causing severe damage to the gastrointestinal tract and even a very small quantity may cause significant morbidity requiring prolonged and repeated hospitalization.

Ingestion: Alkalis cause the most severe corrosive effects on the oesophagus, rather than the stomach as is the case with acids. However, following deliberate ingestion of a large quantity of an alkali both the stomach and small intestine may be involved. The severity of injury depends on a number of factors including the concentration of the agent, the duration of contact and the volume ingested and the presence of food in stomach. It is greatest where the pH is above 12. However, pH is not the only factor which determines the extent to which a substance can cause corrosive injury. Solid preparations and viscous liquids are also more likely to produce severe injury due to prolonged contact.

Following ingestion of a small amount, the injury is usually limited to the oropharyngeal region and the oesophagus. The greater the volume the greater the risk of duodenal and gastric damage.

Oesophageal changes can be divided into 3 stages:

1) acute necrotic phase in which cell death occurs due to coagulation of intracellular protein,
2) intense inflammatory reaction in viable tissues surrounding the necrotic area, thrombosis of vessels occurs, and
3) sloughing of superficial necrotic layer 2 to 4 days later.

Classification or grading of Oesophageal Burns:

First Degree: mucosa only, hyperaemic oedematous mucosa, may be superficial sloughing;

Second degree: destruction of mucosa and submucosa, penetration into muscle layers, exudate is present, erosions and shallow ulcers;

Third degree: full thickness injury, possible perforation, deep ulcerations, black coagulation.

Skin burns: Alkali injuries differ from those of other burns for a number of reasons. The injury may be painless and not be immediately evident. This initial lack of pain may lead to a delay in treatment. The injury can progress over several hours and the skin may be discoloured brown or black within a short period of time, these factors make initial assessment of the burn depth difficult. Also, there may be recurring skin breakdown over a long period after the initial injury which can complicate and delay recovery.

Ocular burns: Alkali burns of the eye are very serious because they cause disruption of the protective permeability barriers and rapidly penetrate the cornea and anterior chamber resulting in blindness.

2.2 Summary of clinical effects

Ingestion

This may cause an immediate burning pain in the mouth, oesophagus and stomach (retrosternal and epigastric pain), with swelling of the lips. This is followed by vomiting, haematemesis, increased salivation, ulcerative mucosal burns, dyspnoea, paralytic ileus, stridor, dysphagia and shock. Oesophageal and pharyngeal oedema may occur.

Acute complications: These include gastrointestinal haemorrhage and perforation of the gut (mediastinitis and peritonitis as suggested by increasing abdominal pain, persistent vomiting, direct and indirect tenderness and a rigid abdominal wall). Dyspnoea and stridor may occur and in severe cases there may be upper airway obstruction. Aspiration can be a serious complication.

Late complications: Oesophageal stricture and pyloric stenosis may occur as late complications. Stricture formation usually begins to develop 14 to 21 days after ingestion. Most strictures manifest within the first two months. Strictures may prevent an adequate nutritional intake and in severe cases patients may be unable to swallow their own saliva.

Gastric necrosis and stricture may occur, usually in patients who have oesophageal injury as well. Gastric injury is more likely to occur following ingestion of liquid alkali rather than a solid. The small intestine may also be involved.

Oesophago-aortic fistulae and rupture of the aorta are rare complications of corrosive ingestion. Tracheo-oesophageal fistulae and less commonly, broncho-oesophageal fistulae, have been reported following ingestion of alkalis. Perforation and fistula may develop as a consequence of invasive diagnostic procedure and treatment (i.e. oesophageal dilatation).

Severe corrosive injury to the stomach may result in small scarred immobile stomach and in such cases small, frequent intakes of food may be necessary to prevent dumping syndrome. Achlorhydria with reduced or absent intrinsic factor may also occur.

Long-term risks: Patients with oesophageal strictures are at significant risk for developing squamous cell carcinoma, which can occur years after the initial injury. The vast majority of data is on sodium hydroxide about which there have been more reports of ingestion. The incidence of carcinoma following oesophageal injury from sodium hydroxide is 0.8 to 4%.

Skin exposure

Alkalis can cause deep penetrating burns and necrosis. There is also a risk of secondary infection of the damaged skin.

Eye contact

Alkalis are responsible for some of the most severe, blinding injuries to the eye. Urgent ophthalmological referral is required. Even if the initial manifestations are mild, the injuries may develop into opacification, vascularisation, ulcerations and perforations.

2.3 Diagnosis

The history of exposure to alkali vapours, solutions or solids and the evidence of corrosive lesions in the gastrointestinal tract, skin or eyes are essential for the diagnosis. pH indicator shows alkaline reaction in contact with affected tissues or stomach content. Chemical identification of the toxic agent will help to confirm the diagnosis.

2.4 First aid measures and management principles

Ingestion:

Asymptomatic/mildly symptomatic patients: It should be noted that oesophageal damage may occur in the absence of oral burns. Gastric lavage and emesis are contraindicated because of the risks of further injury on re-exposure of the oesophagus. Nasogastric aspiration of the stomach contents is probably less effective for ingestion of alkalis than for acids, since alkalis tend to damage the oesophagus rather than the stomach. Neutralizing chemicals should never be given because heat produced during neutralization could exacerbate any injury.

Gastro-oesophagoscopy should be undertaken within 12 to 24 hours of the event to assess the extent and severity of the injury. Endoscopy is contraindicated in patients with third degree burns of the hypopharynx, burns involving the larynx or those with respiratory distress. Traditionally the endoscopist terminates the procedure at the first deep, penetrating and/or circumferential burn because of the risk of perforation. However some

physicians now recommend the use of a flexible endoscope to include the stomach and small intestine (panendoscopy) regardless of the presence of second or non-perforating third degree burns to the oesophagus. If perforation is suspected or severe hypopharyngeal burns are present, radiographic studies with water-soluble contrast media may be used instead.

Patients with grade 1 oesophageal burns may be discharged after 2 to 3 days, if they are able to take oral fluids and semi-solids. Those with grade 2 burns should be admitted and given parenteral nutrition. Intensive care is usually required for patients with grade 3 burns. For discussion on the use of steroids and antibiotics - see below.

Severely affected patients: In severely affected patients aggressive intervention is essential. Urgent assessment of the airway and endoscopic evaluation is required. A supraglottic-epiglottic burn with erythema and oedema is usually a sign that further oedema will occur which will lead to airway obstruction and is an indication to evaluate for early intubation or tracheostomy.

Plasma expanders/intravenous fluids for shock and check and correct the acid/base balance. Abdominal and chest X-rays need to be taken to check for perforation. Analgesia will almost certainly be needed. Intubation and ventilation may be necessary for patients with respiratory distress. Parenteral feeding will be necessary. Surgical intervention may also be required for gastrointestinal perforation or haemorrhage.

Late complications: Strictures that prevent adequate nutritional intake and do not respond to dilatation require oesophagectomy and colonic interposition. Surgical intervention may also be required for gastrointestinal perforation or haemorrhage. There may be loss of speech and inability to swallow as a result of severe corrosive injury.

Severe cases of alkali ingestion may result in long-term problems and require prolonged hospitalization and several surgical procedures and psychological treatment is recommended. On discharge all patients must be advised on the possibility of late onset sequelae and advised to return if necessary. In patients who have developed oesophageal stricture monitoring for life is recommended because of the risk of malignant disease.

Dermal injury: The most important therapy for dermal alkali injuries is removal of contaminated clothes and irrigate with copious running water. This effectively cleanses the wound of unreacted chemical, dilutes the chemical already in contact with tissue and restores tissue water lost to the hygroscopic effect of alkalis. The earlier the irrigation is begun the greater the benefit. Irrigation should, therefore, be started as soon as possible, until the slippery and soapy sensation is no longer felt in the affected area. The testing the pH of the skin immediately after irrigation may be misleading. It is recommended that 15 minutes elapse before this is undertaken to allow residual alkali to diffuse up from the deeper regions of the dermis. Referral to a burns unit is recommended.

Ocular injury: Copious and immediate irrigation of exposed eyes is essential. Contact lenses should be removed prior to irrigation. Tepid water (preferably sterile) or normal saline may be used, although other solutions have been employed in an emergency including tap water. Particulate matter should be removed with cotton wool buds or forceps. The pH of the cornea and irrigating fluid from the eye should be monitored with universal indicator paper. Irrigation should be continued until the pH of the eye is normal and remains so for 2 hours. Pain and blepharospasm may make irrigation difficult and the

use of anaesthetic drops (e.g. amethocaine, lignocaine) may be needed to facilitate thorough irrigation. A lid speculum may be used if required.

It is essential that the whole eye is irrigated including under the upper and lower lids. After irrigation further treatment is aimed at preventing optic nerve damage from raised intraocular pressure and to protect the cornea from ulceration, perforation and infection. Urgent referral to an ophthamologist is recommended.

The use of steroids in corrosive injury

Steroids have an anti-inflammatory effect and decrease fibroblastic activity and scar tissue formation. Animal data has demonstrated that strictures formed in subjects given steroids have been less well structured with fewer inflammatory changes and less fibrin deposition. The use of steroids for corrosive injury in man is a controversial subject which has generated a huge amount of literature (see section 10).

Steroids are valuable in the management of laryngeal oedema, a complication of alkali ingestion.

The main aim of steroids is to reduce stricture formation. The role of steroids in alkali injury is still the subject of much debate, however most authors agree that patients with first degree burns do not require steroids since these burns usually heal without stricture formation. The difficulty there is determining the severity of the injury from oesophagoscopy since it is difficult to determine the depth of the burn and the endoscope is sometimes not passed beyond the first identified burn due to the risk of perforation. Some burns are so severe and extensive that strictures may develop despite steroid therapy and may be delayed.

However, there is no clinical evidence that steroid therapy is more effective than non-steroid therapy in reducing oesophageal stricture in any patient, even those with second degree burns. Some authors believe there is no place for steroid therapy in the management of corrosive injury.

Contraindications and problems in steroid therapy:

It should be noted that there are definite contraindications to the use of steroids, these are as follows:

a) infections
b) perforation of the gastrointestinal tract or secondary mediastinitis
c) gastrointestinal bleeding
d) active ulcer

Steroids depress the immune system and as a result the patient is more susceptible to infection. Also steroids may mask the signs and symptoms of infection as well as those of perforation and peritonitis. Steroid therapy may also result in a thin-walled oesophagus vulnerable to perforation due to reduced wound healing and scar formation.

When to begin therapy:

Once the decision has been made to use steroids, therapy should be started within 24 to 48 hours of the injury because the major inflammatory insult occurs within the first 48 hours and after this time steroids have little antifibroblastic activity. Therapy started later may reduce scar formation but all evidence indicates that the best results are obtained with early institution of therapy. The short duration of steroid therapy should not produce a significant reduction in intrinsic steroid production or alter the metabolic balance.

The use of antibiotics in corrosive injury

Antibiotics should be used in all patients with evidence of infection. Some authors suggest that prophylactic antibiotics should be given in patients on steroid therapy, but others considered this unnecessary since the risk of infection is low.

Adjunctive treatment

The use of H2-blockers and metoclopramide may help to prevent secondary acid injury to the oesophagus.

3. PHYSICO-CHEMICAL PROPERTIES

3.1 Origin of the substance

3.2 Chemical structure

Calcium hydroxide

Molecular mass: 74.1

Chemical formula: $Ca(OH)_2$

Potassium hydroxide

Molecular mass: 56.1

Chemical formula: KOH

Sodium hydroxide

Molecular mass: 40.0

Chemical formula: NaOH

3.3 Physical properties

3.3.1 Colour

Depends on the substance and formulations.

Calcium hydroxide: white/greyish-white

Potassium hydroxide: white

3.3.2 State/Form

Depends on the substance and formulations.

Calcium hydroxide: solid-powder

Potassium hydroxide: deliquescent solid

3.3.3 Description

Calcium hydroxide

Melting point (decomposes): 580°C

Relative density (water = 1): 2.

Solubility in water: None

Potassium hydroxide
Boiling point: 1324°C
Melting point: 380°C
Relative density (water = 1): 2.04
Solubility in water, g/100 mL at 25°C: 110
Vapour pressure, kPa at 714°C: 0.13

Sodium hydroxide
Boiling point: 1390°C
Melting point: 318°C
Relative density (water = 1): 2.1
Solubility in water, g/100 mL at 20°C: 109

3.4 Hazardous characteristics

Calcium hydroxide: The substance decomposes on heating producing calcium oxide. The substance is a medium strong base.

Potassium hydroxide: The substance is a strong base, it reacts violently with acid and is corrosive in moist air towards metals such as zinc, aluminium, tin and lead forming a combustible/explosive gas. Rapidly absorbs carbon dioxide and water from air. Contact with moisture or water will generate heat .

Sodium hydroxide: The substance is a strong base, it reacts violently with acid and is corrosive in moist air to metals like zinc, aluminium, tin and lead forming a combustible gas. Attacks some forms of plastics, rubber and coatings. Contact with moisture or water may generate heat.

4. USES

4.1 Uses

4.1.1 Uses

4.1.2 Description

Alkalis are present in a number of household products (e.g. drain cleaners, oven cleaners, bleaches, dishwasher products, some paint strippers) and are also used in industry. Clinitest tablets used to test urine of diabetics, swimming pool sanitizers and hair relaxer products also contain alkalis.

4.2 High risk circumstance of poisoning

Intentional Exposure:
Alkalis are present in dish washing agents, hair relaxing agents, drain cleaning agents, oven cleaning agents and bleaching agents. So, employees with access to alkalis at work include drain cleaners, hair stylists (alkalis are present in hair relaxing agents) and any other employee who has access to the above mentioned agents.

4.3 Occupationally exposed populations

People engaged in occupations using the above mentioned substances can have accidental skin and ocular exposure

5. ROUTES OF EXPOSURE

5.1 Oral

Alkalis cause the most severe corrosive effects on the oesophagus rather than the stomach, as is the case with acids. However, following deliberate ingestion of a large quantity of an alkali both the stomach and small intestine may be involved. The severity of injury depends on a number of factors including the concentration of the agent, the duration of contact and the volume ingested and the presence of food in stomach. It is greatest where the pH is above 12. However, pH is not the only factor that determines the extent to which a substance can cause corrosive injury. Solid preparations and viscous liquids are also more likely to produce severe injury due to prolonged contact. Following ingestion of a small amount the injury is usually limited to the oropharyngeal region and the oesophagus. The greater the volume the greater the risk of duodenal and gastric damage.

5.2 Inhalation

Sodium hypochlorite solutions may release small amounts of hypochlorous acid and chlorine gas, but usually the concentrations are too low to cause damage. Mixing solutions of ammonia and sodium hypochlorite produces monochloramine (NH_2Cl) and dichloramine ($NHCl_2$) fumes. The release of chloramine fumes in a confined space can cause chemical pneumonitis. Prolonged inhalation of chloramine fumes can produce obstructive pulmonary deficits, chest infiltrates and acute pulmonary oedema.

5.3 Dermal

Alkali injuries differ from those of other burns for a number of reasons. The injury may be painless and not be immediately evident. This initial lack of pain may lead to a delay in treatment. The injury can progress over several hours and the skin may be discoloured brown or black within a short period of time, these factors make initial assessment of the burn depth difficult. Also, there may be recurring skin breakdown over a long period after the initial injury which can complicate and delay recovery (O'Donoghue et al., 1996).

5.4 Eye

Alkali burns of the eye are very serious because they cause disruption of the protective permeability barriers and rapidly penetrate the cornea and anterior chamber resulting in blindness.

5.5 Parenteral

Not relevant.

5.6 Other

Not relevant.

6. KINETICS

6.1 Absorption by route of exposure

6.2 Distribution by route of exposure

6.3 Biological half-life by route of exposure

6.4 Metabolism

6.5 Elimination and excretion

7. TOXICOLOGY

7.1 Mode of action

Alkalis cause liquefactive necrosis with saponification of fats and solubilisation of proteins, they are also hygroscopic and will absorb water from the tissues. These effects result in adherence and deep penetration into the tissues.

7.2 Toxicity

7.2.1 Human data

7.2.1.1 Adults

Toxic effects mainly occur through ingestion and ocular exposure. Further details on this are given in other relevant sections.

7.2.1.2 Children

Children are commonly reported to ingest corrosive substances but severe effects are relatively rare. Several studies have been carried out in children in an effort to correlate clinical effects and injury. Gaudreault et al. (1983) found that signs and/or symptoms do not adequately predict the presence or severity of an oesophageal lesion. Crain et al. (1984) found that the presence of two or more signs or symptoms (vomiting, drooling, stridor) may be a reliable predictor of oesophageal injury. In another study, prolonged drooling and dysphagia (12 to 24 hours) were observed to predicted oesophageal scar formation with 100% sensitivity (Nuutinen et al., 1994). In a study of 224 children (aged 0 to 14 years) serious complications were due to ingestion of sodium hydroxide or a dishwasher product.

Children without any signs or symptoms at the first examination did not develop stricture or epiglottal oedema (Clausen et al., 1994).

7.2.2 Relevant animal data

7.2.3 Relevant in vitro data

7.2.4 Workplace standards

7.2.5 Acceptable daily intake (ADI)

Not relevant.

7.3 Carcinogenicity

Increased risk of oesophageal cancer has been reported following ingestion of alkalis.

7.4 Teratogenicity

No data available

7.5 Mutagenicity

No data available

7.6 Interactions

8. TOXICOLOGICAL ANALYSES AND BIOMEDICAL INVESTIGATIONS

8.1 Material sampling plan

8.1.1 Sampling and specimen collection

8.1.1.1 Toxicological analyses

8.1.1.2 Biomedical analyses

8.1.1.3 Arterial blood gas analysis

8.1.1.4 Haematological analyses

8.1.1.5 Other (unspecified) analyses

8.1.2 Storage of laboratory samples and specimens

8.1.2.1 Toxicological analyses

8.1.2.2 Biomedical analyses

8.1.2.3 Arterial blood gas analysis

8.1.2.4 Haematological analyses

8.1.2.5 Other (unspecified) analyses

8.1.3 Transport of laboratory samples and specimens

8.1.3.1 Toxicological analyses

8.1.3.2 Biomedical analyses

8.1.3.3 Arterial blood gas analysis

8.1.3.4 Haematological analyses

8.1.3.5 Other (unspecified) analyses

8.2 Toxicological Analyses and Their Interpretation

8.2.1 Tests on toxic ingredient(s) of material

8.2.1.1 Simple Qualitative Test(s)

8.2.1.2 Advanced Qualitative Confirmation Test(s)

8.2.1.3 Simple Quantitative Method(s)

8.2.1.4 Advanced Quantitative Method(s)

8.2.2 Tests for biological specimens

8.2.2.1 Simple Qualitative Test(s)

8.2.2.2 Advanced Qualitative Confirmation Test(s)

8.2.2.3 Simple Quantitative Method(s)

8.2.2.4 Advanced Quantitative Method(s)

8.2.2.5 Other Dedicated Method(s)

8.2.3 Interpretation of toxicological analyses

8.3 Biomedical investigations and their interpretation

8.3.1 Biochemical analysis

8.3.1.1 Blood, plasma or serum
"Basic analyses"
"Dedicated analyses"
"Optional analyses"

8.3.1.2 Urine
"Basic analyses"
"Dedicated analyses"
"Optional analyses"

8.3.1.3 Other fluids

8.3.2 Arterial blood gas analyses

8.3.3 Haematological analyses
"Basic analyses"
"Dedicated analyses"
"Optional analyses"

8.3.4 Interpretation of biomedical investigations

8.4 Other biomedical (diagnostic) investigations and their interpretation

8.5 Overall interpretation of all toxicological analyses and toxicological investigations

8.6 References

9. CLINICAL EFFECTS

9.1 Acute poisoning

9.1.1 Ingestion

This may cause an immediate burning pain in the mouth, oesophagus and stomach (retrosternal and epigastric pain), with swelling of the lips. This is followed by vomiting, haematemesis, increased salivation, ulcerative mucosal burns, dyspnoea, paralytic ileus, stridor, dysphagia and shock. Oesophageal and pharyngeal oedema may occur.

Acute complications: these include gastrointestinal haemorrhage and perforation of the gut leading to mediastinitis and peritonitis (suggested by increasing abdominal pain, persistent vomiting, direct and indirect tenderness and a rigid abdominal wall). Dyspnoea and stridor may occur and in severe cases there may be upper airway obstruction. Aspiration can be a serious complication.

Late complications: oesophageal stricture and pyloric stenosis may occur as late complications. Stricture formation usually begins to develop 14 to 21 days after ingestion. Most strictures manifest within the first two months. Strictures may prevent an adequate nutritional intake and in severe cases patients may be unable to swallow their own saliva. Gastric necrosis and stricture may occur, usually in patients who have oesophageal injury as well. Gastric injury is more likely to occur following ingestion of liquid alkali rather than a solid.

The small intestine may also be involved. Oesophago-aortic fistulae and rupture of the aorta are rare complications of corrosive ingestion. Tracheo-oesophageal fistulae and less commonly, broncho-oesophageal fistulae, have been reported following ingestion of alkalis. Perforation and fistula may develop as a consequence of invasive diagnostic procedure and treatment (i.e. oesophageal dilatation).

Severe corrosive injury to the stomach may result in small scarred immobile stomach and in such cases small, frequent intakes of food may be necessary to prevent dumping syndrome. Achlorhydria with reduced or absent intrinsic factor may also occur.

Long-term risks: alkalis are known to increase the risk of oesophageal cancer, which can occur years after the initial injury (Appelqvist and Salmo, 1980; Benirscke, 1981; Isolauri and Markkula, 1989; Kinnman et al., 1968). The vast majority of data is on sodium hydroxide about which there have been more reports of ingestion. The incidence of carcinoma following oesophageal injury from sodium hydroxide is 0.8 to 4%.

9.1.2 Inhalation

Not relevant

9.1.3 Skin exposure

Alkalis can cause deep penetrating burns and necrosis. There is also a risk of secondary infection of the damaged skin.

9.1.4 Eye contact

Alkalis are responsible for some of the most severe, blinding injuries to the eye. Urgent ophthalmological referral is required.

9.1.5 Parenteral exposure

Not relevant.

9.1.6 Other

Not relevant.

9.2 Chronic poisoning

9.2.1 Ingestion

9.2.2 Inhalation

9.2.3 Skin exposure

9.2.4 Eye contact

9.2.5 Parenteral exposure

9.2.6 Other

9.3 Course, prognosis, cause of death

See Section 9.1

9.4 Systematic description of clinical effects

9.4.1 Cardiovascular

Liquefaction necrosis and saponification of fats can cause thrombosis of blood vessels of the gastrointestinal tract.

9.4.2 Respiratory

Oedema of upper airways can cause breathing difficulty. Mixing solutions of ammonia and sodium hypochlorite produces monochloramine (NH_2Cl) and dichloramine ($NHCl_2$) fumes. The release of chloramine fumes in a confined space can cause chemical pneumonitis. prolonged inhalation of chloramine fumes can produce obstructive pulmonary deficits, chest infiltrates and acute pulmonary oedema.

9.4.3 Neurological

If the patient goes into shock, it may cause permanent neurological damage.

9.4.3.1 Central nervous system (CNS)

No data available

9.4.3.2 Peripheral nervous system

No data available

9.4.3.3 Autonomic nervous system

No data available

9.4.3.4 Skeletal and smooth muscle

No data available

9.4.4 Gastrointestinal

Ingestion may cause an immediate burning pain in the mouth, oesophagus and stomach (retrosternal and epigastric pain), with swelling of the lips. This is followed by vomiting, haematemesis, increased salivation, ulcerative mucosal burns, dyspnoea, paralytic ileus, stridor, dysphagia and shock. Oesophageal and pharyngeal oedema may occur

Acute complications: these include gastrointestinal haemorrhage and perforation of the gut leading to mediastinitis and peritonitis (suggested by increasing abdominal pain, persistent vomiting, direct and Indirect tenderness and a rigid abdominal wall).

Late complications: oesophageal stricture and pyloric stenosis may occur as late complications. Stricture formation usually begins to develop 14 to 21 days after ingestion. Most strictures manifest within the first two months. Strictures may prevent an adequate nutritional intake and in severe cases patients may be unable to swallow their own saliva. Gastric necrosis and stricture may occur, usually in patients who have oesophageal injury as well. Gastric injury is more likely to occur following ingestion of liquid alkali rather than a solid.

The small intestine may also be involved. Oesophago-aortic fistulae and rupture of the aorta are rare complications of corrosive ingestion. Tracheo-oesophageal fistulae and less commonly, broncho-oesophageal fistulae, have been reported following ingestion of alkalis.

9.4.5 Hepatic

No data available

9.4.6 Urinary

Low urine output could occur in acute renal failure.

9.4.6.1 Renal

Hypovolaemia can lead to acute renal failure.

9.4.6.2 Other

9.4.7 Endocrine and reproductive systems

No data available

9.4.8 Dermatological

Skin irritation may occur through prolonged exposure.

9.4.9 Eye, ear, nose, throat: local effects

Ocular exposure to an alkali produces eye pain, tearing, foreign body sensation, conjunctival erythema, corneal ulceration and opacification, decreased visual acuity, eyelid burns and oedema

9.4.10 Haematological

No data available

9.4.11 Immunological

No data available

9.4.12 Metabolic

9.4.12.1 Acid-base disturbances
Extensive gastrointestinal necrosis can cause metabolic acidosis and elevated serum lactate levels.

9.4.12.2 Fluid and electrolyte disturbances
There can be hypovolaemia and electrolyte imbalances following gastrointestinal injury.

9.4.12.3 Others

9.4.13 Allergic reactions
No data available

9.4.14 Other clinical effects

9.4.15 Special risks

9.5 Other

9.6 Summary

10. MANAGEMENT

10.1 General principles

Ingestion:
Asymptomatic / mildly symptomatic patients: It should be noted that oesophageal damage may occur in the absence of oral burns. Gastric lavage and emesis are contraindicated because of the risks of further injury on re-exposure of the oesophagus. Nasogastric aspiration of the stomach contents is probably less effective for ingestion of alkali than for acids, since alkalis tend to damage the oesophagus rather than the stomach. Oral fluids may be given unless there is evidence of severe injury. Neutralising chemicals should never be given because heat is produced during neutralisation and this could exacerbate any injury.

Gastro-oesophagoscopy should be undertaken within 12 to 24 hours of the event to assess the extent and severity of the injury. Endoscopy is contraindicated in patients with third degree burns of the hypopharynx, burns involving the larynx or those with respiratory distress. Traditionally the endoscopist terminates the procedure at the first deep, penetrating and/or circumferential burn because of the risk of perforation. However some physicians now recommend the use of flexible endoscopy to include the stomach and small intestine (panendoscopy) regardless of the presence of second or non-perforating third degree burns to the oesophagus (Ford, 1991; Meredith, 1996). If perforation is suspected or severe hypopharyngeal burns are present, radiographic studies with water-soluble contrast media may be used instead.

Patients with grade 1 oesophageal burns may be discharged if they are able to take oral fluids. Those with grade 2 burns should be admitted and given parenteral nutrition.

Intensive care is usually required for patients with grade 3 burns. A laparotomy may be required if there is evidence of gastric injury or the gastric pH is persistently alkaline (Meredith, 1996). For discussion on the use of steroids and antibiotics - see below.

Severely affected patients: Treatment is supportive. In severely affected patients aggressive intervention is essential. Urgent assessment of the airway and endoscopic evaluation is required. A supraglottic-epiglottic burn with erythema and oedema is usually a sign that further oedema will occur which will lead to airway obstruction and is an indication for early intubation or tracheostomy.

Give plasma expanders/intravenous fluids for shock and check and correct the acid/base balance. Abdominal and chest X-rays need to be taken to check for perforation. Analgesia will almost certainly be needed. Intubation and ventilation may be necessary for patients with respiratory distress. Parenteral feeding will be necessary.

Late complications: strictures that prevent adequate nutritional intake and do not respond to dilatation require oesophagectomy and colonic interposition. In the case of oesophageal strictures a lumen >10mm does not impede normal life and should not require intervention. Surgical intervention may also be required for gastrointestinal perforation or haemorrhage. There may be loss of speech and inability to swallow as a result of severe corrosive injury. Speech and swallowing rehabilitation is a complex subject and is discussed by Shikowitz et al. (1996) with description of the surgical techniques used and the tools used to determine the success of the reconstruction.

Severe cases of alkali ingestion may result in long-term problems and require prolonged hospitalization and several surgical procedures and psychological treatment is recommended. On discharge all patients must be advised on the possibility of late onset sequelae and advised to return if necessary. In patients who have developed oesophageal stricture monitoring for life is recommended because of the risk of malignant disease.

Dermal injury: The most important therapy for dermal alkali injuries is removal of contaminated clothes and irrigate with copious running water. This effectively cleanses the wound of unreacted chemical, dilutes the chemical already in contact with tissue and restores tissue water lost to the hygroscopic effect of alkalis. The earlier the irrigation is begun the greater the benefit. Irrigation should, therefore, be started as soon as possible. Testing the pH of the skin immediately after irrigation may be misleading. It is recommended that 15 minutes elapse before this is undertaken to allow residual alkali to diffuse up from the deeper regions of the dermis (Herbert and Lawrence, 1989; O'Donoghue et al., 1996). Referral to a burns unit is recommended.

Ocular injury: Copious and immediate irrigation of exposed eyes is essential. Water (preferably sterile) or normal saline may be used, although other solutions have been employed in an emergency including tap water. Particulate matter should be removed with cotton wool buds or forceps. The pH of the cornea and irrigating fluid from the eye should be monitored with universal indicator paper. Irrigation should be continued until the pH of the eye is normal and remains so for 2 hours. Pain and blepharospasm may make irrigation difficult and the use of anaesthetic drops (e.g. amethocaine, lignocaine) may be needed to facilitate thorough irrigation. A lid speculum may be used if required. It is essential that the whole eye is irrigated including under the upper and lower lids. After irrigation further treatment is aimed at preventing optic nerve damage from raised intraocular pressure and to protect the cornea from ulceration, perforation and infection. Urgent referral to an ophthamologist is recommended.

The use of steroids in corrosive injury

Steroids have an anti-inflammatory effect and decrease fibroblastic activity and scar tissue formation. Animal data has demonstrated that strictures formed in subjects given steroids have been less well structured with fewer inflammatory changes and less fibrin deposition. The use of steroids for corrosive injury in man is a controversial subject which has generated a huge amount of literature.

Middlekamp et al. (1969) reported thirty-two cases of oesophageal burns due to alkali injury, none of the patients with first degree burns (nineteen cases) developed oesophageal stricture. One patient (out of six) with second degree burns and all patients with third degree burns (seven) developed oesophageal stricture.

In another study on the use of steroids in children with corrosive injury of the oesophagus, of one hundred and thirty-one children sixty had oesophageal burns. Of these burns, fifty-five were caused by known agents, 91% of which were alkaline. Oesophageal stricture developed in ten of the thirty-one children treated with steroids and in eleven of the twenty-nine controls. Nine of the ten patients in the steroid group had third degree burns and one had second degree injuries, all eleven patients in the control group had third degree burns. Twenty-one patients given steroids and eighteen controls did not develop strictures, of these children all but one had first or second degree injuries (Anderson et al., 1990).

Several authors have found that it is the depth of the initial burn rather than the initial treatment which determines the outcome (Anderson et al., 1990; Moazam et al., 1987; Oakes et al., 1982; Webb et el., 1970).

The main aim of the management of alkali injury is to reduce stricture formation. The role of steroids in alkali injury is still the subject of much debate, however most authors agree that patients with first degree burns do not require steroids since these burns usually heal without stricture formation. The difficulty here is determining the severity of the injury from oesophagoscopy since it is difficult to determine the depth of the burn and the endoscope is sometimes not passed beyond the first identified burn due to the risk of perforation. Some burns are so severe and extensive that strictures may develop despite steroid therapy (Haller et al., 1971) and may be delayed (Middlekamp et al., 1969).

Steroids are valuable in the management of laryngeal oedema, a complication of alkali ingestion.

In summary, steroids are probably most effective for second degree or moderately severe burns (Hawkins et al., 1980; Klein-Schwartz and Oderda, 1983; Webb et al., 1970). They are not necessary for first degree burns and appear to be ineffective in preventing stricture formation following third degree burns. However, there is no clinical evidence that steroid therapy is more effective than non-steroid therapy in reducing oesophageal stricture in any patient, even those with second degree burns. Some authors believe there is no place for steroid therapy in the management of corrosive injury (Di Costanzo et al., 1980; Wijburg et al., 1989). As Oakes et al. (1982) state, clinicians should not feel compelled to institute steroid therapy for caustic oesophagitis simply because it is considered 'standard therapy'.

Contraindications and problems in steroid therapy: It should be noted that there are definite contraindications to the use of steroids, these are as follows:-

a) active infection
b) perforation of the gastrointestinal tract or secondary mediastinitis

c) significant gastrointestinal bleeding
d) history of or active ulcer

Steroids depress the immune system and as a result the patient is more susceptible to infection. Also steroids may mask the signs and symptoms of infection as well as those of perforation and peritonitis. Steroid therapy may also result in a thin-walled oesophagus vulnerable to perforation due to reduced wound healing and scar formation (Cardona and Daly, 1971).

When to begin therapy: Once the decision has been made to use steroids therapy should be started within 24 to 48 hours of the injury because the major inflammatory insult occurs within the first 48 hours and after this time steroids have little antifibroblastic activity. Therapy started later may reduce scar formation but all evidence indicates that the best results are obtained with early institution of therapy (Haller et al., 1971). The short duration of steroid therapy should not produce a significant reduction in intrinsic steroid production or alter the metabolic balance.

The use of antibiotics in corrosive injury

Antibiotics should be used in all patients with evidence of infection. Some authors suggest that prophylactic antibiotics should be given in patients on steroid therapy (Adam and Birck, 1982; Howell et al., 1992), but others considered this unnecessary (Klein-Schwartz and Oderda, 1983; Wijburg et al., 1989) since the risk of infection is low (Knopp, 1979).

Adjunctive treatment

The use of H2-blockers and metoclopramide may help to prevent secondary acid injury to the oesophagus (Haddad, 1998).

10.2 Life supportive procedures and symptomatic/specific treatment

These measures depend on the patient's clinical condition on presentation. Following is a basic guideline to be used for a patient coming with alkali ingestion.

- Make a proper assessment of airway, breathing, circulation and neurological status of the patient on admission.
- Maintain a clear airway and aspirate secretions from the airway if necessary.
- Administration of oxygen and/or intubating the patient may be needed.
- Monitor blood pressure, fluid and electrolyte balance and acid-base balance, depending on the patient's clinical condition.

10.3 Decontamination

Gastric lavage and emesis are contraindicated because of the risks of further injury on re-exposure of the oesophagus.

10.4 Enhanced elimination

See section 10.1

10.5 Antidote treatment

10.5.1 Adults

There is no specific antidote.

10.5.2 Children

There is no specific antidote.

10.6 Management discussion

See section 10.1

11. ILLUSTRATIVE CASES

11.1 Case reports from literature

12. Additional information

12.1 Specific preventive measures

Rescuers, first-aid personnel and medical professionals should use appropriate protective clothing/gloves and where necessary employ respiratory protection.

12.2 Other

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