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# Potential mechanisms of death in cases of fatal acid attacks

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## Abstract

Acid attacks refer to assaults where caustic substances such as an acid are thrown onto a victim. The usual purpose is to maim and disfigure and cause lifelong health and societal issues. Deaths uncommonly occur. Three cases are described involving females who were aged 14, 20 and 35 years respectively, who survived for some time after the attacks but later died. Postmortem findings confirmed that the deaths were due to septicemia and multiorgan failure. After an acid attack, death may be caused by a range of immediate, early and delayed complications. Hypovolemic shock may occur from loss of fluid exuding from the sites of deep burns. If the caustic agent has been inhaled or swallowed there may be mucosal, submucosal or deeper tissue injuries associated with mucosal edema and sloughing of pseudomembranes resulting in critical narrowing of the airways. Inhalation of fumes may also result in diffuse alveolar damage as a significant pathological finding. Further complications include acute renal failure, septicemia, acute respiratory distress syndrome and multiorgan failure. The prognosis of such injuries depends on the extent of the body surface that has been burned, the presence and extent of inhalation injuries, concomitant comorbid conditions and the age of the victim.

## Keywords

Acid attack · Vitriolage · Caustic burns · Death · Forensics

## Introduction

Acid attacks, also known as vitriolage, refer to assaults that are characterized by dousing of a victim with a caustic substance such as an acid; this is most often sulphuric or nitric acid, but it may also involve alkaline solutions such as caustic soda (sodium hydroxide) or ammonia [1, 2]. The incidence and reasons for acid attacks show considerable geographic variability with attacks in the United Kingdom (UK) most often involving males [3, 4] in situations related to gang activities [5], in contrast to India and adjacent countries where the victims are usually females who have rejected marriage or relationship proposals. Other

reasons for such attacks include dowry or property disputes, or as part of more generalized domestic violence [1, 2]. A similar female predominance among victims has been noted in Colombia and Egypt [6, 7].

Although legislation has been enacted in India to limit the sale of acids [8], it is still widely available in marketplaces (■ Fig. 1) where it is purchased as a cleaning fluid for machinery and pipes, or to refill car batteries [9]. Thus, the number of acid attacks in India has persisted: 222 in 2015, 283 in 2016, 244 in 2017 and 228 in 2018 [10], although these numbers are likely underestimates due to failure of documentation or underreporting of such cases in isolated rural communities.

The manuscript has no associated data.



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**Fig. 1** ▲ A vendor in a market place in India selling bottles of sulphuric acid from the back of his bicycle for as little as 40 IR per bottle (50 cents US)



**Fig. 2** ◀ The face and torso of the victim in case 1 showing extensive deeply ulcerated and granulating burns of the forehead, left arm and chest



**Fig. 3** ◀ Both legs from the victim in case 1 showing extensive deeply ulcerated and granulating burns

The aim of such attacks is not necessarily to cause death, but to inflict significant physical and psychological trauma with ongoing medical issues that may result in a lifetime of suffering, unemployment and social ostracism [1, 2]. Given that deaths occur in only 4% or less of cases, and that the range of possible lethal mechanisms in cases of fatal acid attacks has not been explored in detail [11, 12], the following study was undertaken.

### Material and methods

The pathology archives at the Department of Forensic Medicine, All India Institute of Medical Sciences in New Delhi were searched for illustrative cases, the details of three cases with full information are summarized below.

### Case reports

**Case 1:** A 14-year-old girl presented to hospital with severe burns following an acid attack by a spurned lover. She succumbed to her injuries 11 weeks after the attack.

At autopsy the body was that of an adolescent female of average built and poor nutrition. The face was swollen and the body was pale. Removal of surgical dressings revealed multiple ulcerative lesions in various stages of healing, accompanied by suppuration. The area of the acid burns was approximately 45% of the total body surface (■ Figs. 2 and 3). There was evidence of generalized sepsis with exudates over the cerebral convexities and consolidation of the lungs. Death was attributed to septicemic shock and multiorgan failure

secondary to corrosive burns in a case of assault.

**Case 2:** A 20-year-old woman presented to hospital with severe burns following an acid attack by her husband. She succumbed to her injuries 6 weeks after the assault.

At autopsy the body was that of a young female of average built and poor nutrition. Deep granulating burns were present over the right side of the face and neck, the upper part of the chest, the right side and back of the trunk, the arms and the legs, covering approximately 45% of the total body surface area. There was evidence of skin grafting. The lungs were consolidated with multiple micro-abscesses on cut-section. Death was attributed to septicemic shock and multiorgan failure secondary to corrosive burns in a case of assault.

**Case 3:** A 35-year-old woman presented to hospital with severe burns following an acid attack by her husband. She succumbed to her injuries 3 weeks after the assault.

At autopsy the body was that of a middle-aged female of average built and poor nutrition. Deep granulating burns were present over the face, neck, chest, upper part of the abdomen, back, arms and legs covering approximately 50% of the total body surface area. The lungs were consolidated with multiple micro-abscesses on cut-section. Death was again attributed to septicemic shock and multiorgan failure

Table 1 Possible lethal effects of acid attacks	
Early effects	Upper aerodigestive tract injury
	Lower airway injury
	Pulmonary parenchymal damage/ARDS
	Shock
Later effects	Renal failure
	Sepsis
	Multiorgan failure
ARDS acute respiratory distress syndrome	

ure secondary to corrosive burns in a case of assault.

In addition to the major findings noted for each case there were typical nonspecific findings of multiorgan failure.

## Discussion

Burns are painful injuries that may be caused by a variety of different mechanisms involving fires (the most common [13]), scalding, hot objects, chemicals, electricity and radiation [14]. Burns may also be generated by friction, for example from a rope sliding through the hands, or from sliding along a surface. Acid attacks are chemical burns and are typified by extensive destruction of the skin, soft tissue and bones; however, while each group has characteristic and different features a common element underpinning individual reaction to the trauma is the physiological responses of the body to marked skin loss and/or damage to the upper aerodigestive tract in cases of inhalation injuries. This means that underlying pathological processes and lethal mechanisms are often similar and so extrapolation among the groups can be undertaken.

Concentrated acid dissolves skin and tissues causing extreme pain. As the head and face are the most often targeted sites, significant injuries are often craniocentric with loss of hair, skin of the face and scalp, and the ear and nasal cartilages [1]. Subsequent scarring of the mouth may make speaking, eating and drinking difficult, with scarring of the nose interfering with breathing, and the ears causing deafness. The eyes may be directly damaged by acid with injuries to the eyelids and corneas, or loss of the eyelids may cause subsequent corneal scarring, all contributing to impaired vision and/or blindness.

Burns to the neck, shoulders and upper trunk may lead to dense scarring which impedes normal arm and neck movements [1]. All of these injuries, although not directly life-threatening, result in a poor quality of life and the need for repeated medical procedures over years (if they are available locally and can be afforded), with social ostracism and increased risks of unemployment. The occurrence of anxiety, depression and posttraumatic stress are well-recognized sequelae [15], although accurate data on suicide rates in survivors are not currently available.

While only 2% of injuries have been life-threatening in some studies [16], this has been as high as 8.1% in others [12]. There is a risk of death from a variety of immediate, early and delayed processes, although this separation is somewhat artificial as the underlying pathological responses are not temporally discreet. In the time immediately after the attack there may be shock from loss of fluid exuding from the sites of deep burns. If the caustic agent has been inhaled or swallowed, there may be mucosal, submucosal or deeper tissue injuries associated with mucosal edema and sloughing of pseudomembranes resulting in critical narrowing of the airways. Inhalation of fumes may result in diffuse alveolar damage [17, 18]. If there is survival for some time deaths in one study were due to acute renal failure in 42.1%, septicemia (as in the reported cases, 31.6%), acute respiratory distress syndrome (8.7%) and shock (7%) [19]. The terminal event may be multiorgan failure due to the metabolic consequences of acute renal failure and sepsis (■ Table 1). In thermal burns rhabdomyolysis may contribute to acute renal failure [20] with hypovolemia and sepsis being other common etiological factors [21].

The likelihood of death increases with the amount of body surface that has been burned [22, 23]. Other factors increasing morbidity and mortality are inhalation injuries, concomitant comorbid conditions and the age of the victim, although as can be seen in case 1 the young are still vulnerable [24, 25]; prognostic scoring systems have been developed to assist in predicting the likely outcome [26, 27]. The reported cases and literature demonstrate that acid attacks may kill a victim by a variety of mechanisms, resulting in charges in medicolegal cases escalating to homicide from lesser offences of attempted murder, causing grievous bodily harm, or serious assault.

As can be seen from the reported cases, death may not occur immediately but may take some time due to significant tissue destruction with associated infections and metabolic decompensation. The clinical course of victims prior to death may be very difficult and distressing, adding yet another layer to the degree of vindictiveness that often characterizes these assaults. Not only must legislation be enacted to counter such attacks, but there must also be effective implementation of investigations, legal processing and punishment of perpetrators.

Similar problems have been encountered in dealing with cases of femicide where review of national legislation has demonstrated a paucity of specific laws, despite international initiatives focussing on violence against women [28]. Another issue that was raised in this study that also applies to acid attacks, is non-uniformity in definitions in both the forensic pathology literature and in legislation. It was suggested that standardization of forensic investigations would provide valid data for international comparisons enhancing research [28], and as in the case of acid attacks it would also provide an optimal outcome for victims.

### Practical conclusion

- Acid attacks are often serious assaults where acidic or alkaline fluids are thrown onto a victim.
- The purpose may be to kill the victim, or more often to maim and disfigure resulting in chronic health issues.

- Deaths may occur rapidly from a range of mechanisms including hypovolemic shock, airway injury with critical narrowing, or diffuse alveolar damage from the inhalation of fumes.
- More chronic conditions that may prove fatal are renal failure, septicemia, respiratory distress syndrome and multiorgan failure.
- The victim's responses may be influenced by the extent of the injuries, concomitant comorbid conditions and age.
- Non-uniformity in definitions in the forensic pathology literature and in legislation complicates determination of the extent of this problem.
- Standardization of forensic investigations would provide valid data for international comparisons to both improve research and to provide an optimal outcome for victims.

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## Declarations

**Conflict of interest.** R.W. Byard, C. Behera, S.K. Gupta, M. Chauhan and N. Kaur declare that they have no competing interests.

The Study followed Ethical Guidelines stipulated by the All India Institute of Medical Sciences.

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## Mögliche Todesursachen bei tödlichen Säureangriffen

Als Säureanschläge werden Angriffe bezeichnet, bei denen ätzende Substanzen wie Säure auf ein Opfer geworfen werden. In der Regel wird damit bezweckt, das Opfer zu verstümmeln und zu entstellen und damit lebenslange gesundheitliche und soziale Probleme zu verursachen. Todesfälle sind eher selten. Es werden drei Fälle beschrieben, bei denen Frauen im Alter von 14, 20 bzw. 35 Jahren nach den Angriffen noch einige Zeit überlebten, später aber starben. Der Obduktionsbefund bestätigte, dass die Todesfälle auf Septikämie und Multiorganversagen zurückzuführen waren. Nach einem Säureanschlag kann der Tod durch eine Reihe von unmittelbaren, frühen und verzögerten Komplikationen verursacht werden. Ein hypovolämischer Schock kann durch den Verlust von Flüssigkeit entstehen, die aus den tiefen Verbrennungsstellen austritt. Wenn die ätzende Substanz eingeatmet oder verschluckt wurde, kann es zu Verletzungen der Schleimhäute, der Submukosa oder des tieferen Gewebes kommen, die mit Schleimhautödem und dem Ablösen von Pseudomembranen einhergehen und zu einer kritischen Verengung der Atemwege führen. Das Einatmen von Dämpfen kann auch zu einer diffusen Alveolarschädigung als signifikantem pathologischem Befund führen. Weitere Komplikationen sind akutes Nierenversagen, Septikämie, akutes Atemnotsyndrom und Multiorganversagen. Die Prognose solcher Verletzungen hängt von der Größe der verbrannten Körperoberfläche, dem Vorhandensein und Ausmaß von Inhalationsverletzungen, begleitenden Erkrankungen und dem Alter des Opfers ab.

## Schlüsselwörter

Säureangriff · Vitriolage · Ätzende Verbrennungen · Tod · Forensik

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## Umgang mit ChatGPT & Co.

Der Hype um den Chatbot „ChatGPT“ des amerikanischen Unternehmens OpenAI ist enorm und künstliche Intelligenz (KI) spätestens damit wohl fest im Bewusstsein der Öffentlichkeit angekommen. Texte aus der Feder eines *Large Language Models (LLM)* wie ChatGPT können in Zukunft auch in wissenschaftlichen Arbeiten zu finden sein. Hierzu hat sich die Zeitschrift *Nature* am 24. Januar 2023 in einem bemerkenswerten Editorial geäußert („Tools such as ChatGPT threaten transparent science; here are our ground rules for their use“)\* und folgende **Grundsätze zur Nutzung von LLMs** festgelegt:

- **Es wird kein LLM-Tool als Autor einer Forschungsarbeit akzeptiert. Geschuldet ist dies der Einsicht, dass eine Autorenschaft immer mit Verantwortung und einer Rechenschaftspflicht für die Arbeit einhergeht und KI-Tools diese Verantwortung nicht übernehmen können.**
- **Autorinnen und Autoren, die LLM-Werkzeuge in ihrer Forschungsarbeit oder zum Verfassen von Texten verwenden, müssen deren Einsatz in ihren Beiträgen dokumentieren.**

\*<https://www.nature.com/articles/d41586-023-00191-1>