

Management of the effects of exposure to tear gas

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Despite the frequent use of riot control agents by European law enforcement agencies, limited information exists on this subject in the medical literature. The effects of these agents are typically limited to minor and transient cutaneous inflammation, but serious complications and even deaths have been reported. During the 1999 World Trade Organisation meeting and at the 2001 Summit of the Americas in Quebec, exposure to tear gas was the most common reason for medical consultations.^{1,2} Primary and emergency care physicians play a role in the first line management of patients as well as in the identification of those at risk of complications from exposure to riot control agents. In 1997 the National Poisons Information Service in England received 597 inquiries from doctors seeking advice about problems related to crowd control.³ Our article reviews the different riot control agents, including the most common tear gases and pepper sprays, and provides an up to date overview of related medical sequelae.

Sources and selection criteria

We searched the following resources for relevant information on the medical toxicity and management of acute exposure to tear gas and pepper spray: Medline, PreMedline, Embase, CINAHL, SCIRUS, the Cochrane Library, ISI Web of Knowledge, Toxnet, Google Scholar, and personal archives. We used the subject headings “riot control agents”, “pepper spray”, “lacrimator”, “tear gas”, “irritants”, “incapacitating agents”, as well as the toxicological terms “chlorobenzylidene-malononitrile”, “chloroacetophenone”, “dibenzoxazepine”, “chlorodiphenylarsine” and “capsaicin”. We also searched the reference lists for additional articles. The overall evidence supporting the current therapeutic approach to patients exposed to tear gas or pepper spray is of poor quality.

What is a tear gas?

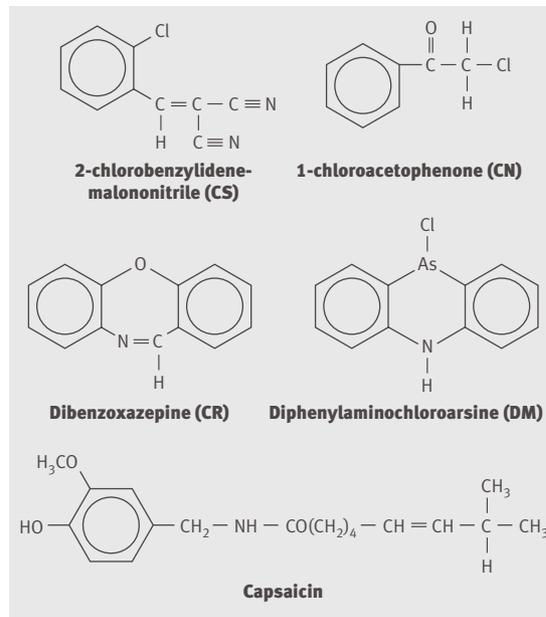
Tear gases (along with pepper sprays, toxic emetics, and some sedative substances) are among the so called riot control agents.⁴ A tear gas is actually not a gas at all, but a toxic chemical irritant in the form of powder or drops mixed to variable concentrations (1-5%) in a

solvent, and delivered with a dispersion vehicle (a pyrotechnically delivered aerosol or spray solution).^{4,5} Tear gases are not currently considered as chemical weapons by Western countries. Since the 1950s, they have been mainly used by law enforcement agencies for crowd control purposes in most European countries, including the United Kingdom, France, Germany, and Switzerland. Tear gases are also used in military training exercises to test the rapidity or efficacy of protective measures in the event of a chemical attack.

Of the known disabling chemical irritants (of which there are more than a dozen), the five that are traditionally used in the European Union are chlorobenzylidene-malononitrile (also known as CS, after the chemists Corson and Stoughton who first synthesised it), chloroacetophenone (CN or “Mace”), dibenzoxazepine (CR), oleoresin capsicum (OC), and pelargonic acid vanillylamide (PAVA) (figure).⁶ Diphenylamino-chloroarsine (DM or adamsite) is an irritating and harassing arsenic based agent used in some countries outside the EU. Oleoresin capsicum is a mixture of cayenne pepper extracts, of which capsaicin is the main active ingredient.^{4,7} Its concentration varies from 1% to 15% depending on the mixture.⁷ Pepper strength is measured in Scoville heat units, ranging from zero for green pepper to 15 million units for pure capsaicin.⁸ Pelargonic acid vanillylamide is a new standardised synthetic variant of oleoresin capsicum used mainly in Switzerland, Austria, and Germany.^{6,7}



Use of tear gas at demonstration at the time of the 2003 G8 summit, Lausanne, Switzerland



Chemical structure of riot control agents

How do riot control agents work?

The irritant effects of crowd control agents probably result from the action of chlorine or cyanide groups in addition to alkalisng compounds (figure). These agents interact with muco-cutaneous sensory nerve receptors such as TRPA1 cation channels.⁹ The effect of oleoresin capsicum is linked to a direct stimulation of type C and Aδ sensory nerve endings, provoking an immediate release of the inflammatory P substance.^{7,8}

A toxic effect of the solvent methyl-isobutyl-ketone or of certain metabolites has also been documented in animal experimental studies, in particular for chlorobenzylidene-malononitrile (formation of cyanide and thiosulfate derivatives) and chloroacetophenone (formation of hydrogen chloride).^{7,10,11}

Assessments of the effects of riot control agents must take into account the weather (wind, rain, and ambient temperature) in addition to the characteristics of the site of deployment (open or closed space) as the effects of tear gas are enhanced by heat and by high ambient

TIPS FOR NON-SPECIALISTS

- Medical teams should wear protection for their own safety and to prevent secondary contamination
- Contaminated clothes must be removed; eyes and affected skin surfaces should be cleaned with water
- For persistent ocular symptoms, ophthalmological assessment is recommended
- For severe pulmonary symptoms, oxygen therapy, β2-mimetics and ipratropium aerosols may be required
- For pulmonary symptoms, a 24-48 hour stay in hospital or a discharge home with detailed

humidity.⁴ Characteristics common to all agents include a rapid onset time and a short duration of effects, as well as a wide margin of safety between the incapacitating dose (ICt 50, the concentration (C) that causes incapacitation (I) in 50% of individuals after one minute (t=time)) and the lethal dose (LCt 50, the concentration that causes death (L) in 50% of individuals after one minute).⁴ The agents differ from one another by their duration of action, their toxicity (chloroacetophenone and diphenylaminochloroarsine are more toxic than chlorobenzylidene-malononitrile or dibenzoxazepine), and their physical and chemical characteristics (table 1). Current information on toxicity is largely based on in vitro and animal studies.⁴

What are the medical consequences of acute exposure to tear gas and pepper spray?

There is limited human research on the risks of tear gas in terms of inducing disability or death. The irritant effect of tear gases affects exposed cutaneous and mucous membrane surfaces.^{4,5} Table 2 summarises the medical complications. Clinical experience and retrospective case studies suggest that the cutaneous effect is by far the most serious symptom, including first and second degree burns.^{12,13} Even in minor cases, skin erythema can last several hours. Direct contact with the flame or a hot canister increases the risk of

Table 1 Physical and chemical characteristics of tear gases and pepper spray^{4,7}

Name	Characteristics	Time to activation	Duration of action (minutes)	Relative potency*	ICt 50 (mg/min per m³)†	LCt 50 ‡ (mg/min per m³)
Chloroacetophenone	Apple odour; powder or emulsion; aerosol	3-10 seconds	10-20	1	20-50	8500-25 000
Chlorobenzylidene malononitrile	Pepper odour; microparticles; dispersing effect (grenades)	10-60 seconds	10-30	5	4-20	25 000-100 000
Dibenzoxazepine	Odourless; aerosol; persists for prolonged periods in the environment or on clothes	Instantaneous	15-60	20-50	0.2-1	>100 000
Diphenylaminochloroarsine	Odourless or slightly bitter almond odour; emetic	Rapid	>60	0.5-2	50-100	10 000-35 000
Oleoresin capsicum	Pepper odour; persists for prolonged periods in the environment or on clothes; short distance spray	Rapid	30-60	Not applicable	Not applicable	>100 000

*Refers to the irritant effect.

†ICt 50=the concentration that causes incapacitation in 50% of individuals after one minute.

‡LCt 50=the concentration that causes death in 50% of individuals after one minute.

Factors influencing the effect of exposure to tear gas⁴⁷

Pre-existing conditions and characteristics of the affected person

- Asthma
- Chronic obstructive pulmonary disease
- Cardiovascular disease
- Severe hypertension
- Young children
- Patients over 60 years
- Ocular diseases
- Contact lenses

Environmental factors

- Confined space
- Poor ventilation

Amount and potency of exposure

- High concentration
- Prolonged exposure
- Repeated exposure
- Potent toxicity of the product (chloroacetophenone is more toxic than chlorobenzylidene-malononitrile)

severe lesions.^{14 15} Delayed contact allergy, leukoderma, or exacerbation of pre-existing dermatitis have also been described in case reports.¹⁶

In experimental studies, transient conjunctivitis and blepharospasm occurred a few seconds after exposure and varied with the concentration of the agent and the duration of exposure.⁵ Corneal damage, hyphema, or vitreous haemorrhage have been described in isolated cases.^{5 17}

Case studies indicate that shortness of breath, sore throat, and chest pain are the most common pulmonary complaints, and these typically resolve within 30 minutes.^{5 11} Some authors have also reported bronchospasm and laryngospasm.¹⁸ Delayed

pulmonary oedema has been described in recent case studies, but permanent long term lung damage seems improbable.^{19 20} Several cases of death have been attributed to the use of chloroacetophenone in confined spaces. Some of the deaths in the 1993 siege on the Branch Davidians in Waco, Texas, were attributed to the use of large amounts of chlorobenzylidene-malononitrile in a confined space.^{5 7}

With pepper sprays, the irritant effect is immediate and lasts 30 minutes on average, mainly affecting the eyes, skin, and respiratory tract.^{17 21} Minor side effects (corneal erosion, respiratory irritability) are described in many case reports.²² The rare deaths that have been documented were caused by bronchospasm, pulmonary oedema, or respiratory arrest and occurred mainly in patients with asthma.^{6 7 17} Capsaicin also has neurotoxic and skin desensitising effects (hence its use in treating refractory pain) and animal studies indicate it may play a role as a procarcinogen after repeated cutaneous or digestive system contact.⁶

Avoidance of exposure and initial management of people exposed to tear gas

The best way for people (including medical staff) to avoid exposure to crowd control agents is obviously not to enter areas that pose a risk of exposure and to move away from these areas quickly if such agents are used. However, emergency medical staff do often have to go near or into such areas to treat affected people, so they must protect themselves by avoiding gaseous areas and by staying on higher ground whenever possible. As tear gases are heavier than air, the patient should be lifted off the ground as quickly as possible and the emergency medical vehicles should be parked in higher areas.

In clinical experience, tear gas or pepper spray has caused secondary contamination of healthcare staff as a result of contact with contaminated patients.^{23 24} Therefore, experts recommend that the initial medical management of patients exposed to tear gases should

Table 2 | Clinical manifestations and potential complications^{4 6 7}

Area affected	Clinical manifestations	Potential complications	Potential sequelae
Eyes	Tearing, burning sensation; blepharospasm; photophobia; corneal oedema (OC)	Keratitis (CN); corneal erosion (OC); intraocular haemorrhage	Cataract; glaucoma
Respiratory tract	Severe rhinorrhoea (CS); sneeze, cough, dyspnoea (CS); pharyngitis; tracheal bronchitis	Bronchospasm, hypoxaemia (CN); delayed pulmonary oedema (CS)	Reactive airways dysfunction syndrome; asthma (possibly)
Cardiovascular system	Hypertension (CS)	Heart failure; cerebral haemorrhage	Not described
Skin	Rash; oedema; erythema; blistering (CS)	Irritant dermatitis (CN); facial oedema (CN); aggravation of dermatitis	Allergic dermatitis (CN)
Digestive tract*	Buccal irritation, salivation (CS); odynodysphagia; abdominal pain; diarrhoea; nausea; vomiting (DM)	Liver toxicity (CS)	Not described
Nervous system	Trembling (DM) Agitation, anxiety	Hysterical reaction	Not described

Some tear gases are more likely to induce specific complications (as noted by abbreviations): CN = chloroacetophenone; CS = o-chlorobenzylidene malononitrile; CR= dibenzoxazepine; DM = diphenylaminochloroarsine; OC = oleoresin capsicum.

*In rare cases the digestive tract may be affected by ingestion.

Additional educational resources**Useful websites**

- US Centers for Disease Control and Prevention (www.bt.cdc.gov/agent/riotcontrol)—Information about case definition and about symptoms, signs, and differential diagnosis

Information for the public and patients

- US Centers for Disease Control and Prevention (www.bt.cdc.gov/agent/riotcontrol/pdf/riotcontrol_factsheet.pdf)—Overview of riot control agents, including symptoms, signs, and treatment
- Chemical Weapons Convention (www.opcw.org/chemical-weapons-convention)—Convention on the prohibition of the development, production, stockpiling, and use of chemical weapons and on their destruction

be symptomatic and consist primarily of non-specific chemical decontamination.²⁵ Identification of affected people and appropriate personal protection (such as clothes gathered at the wrists and neck; gloves; and surgical masks) can prevent secondary contamination of medical staff.²³

An initial triage allows for identification of at-risk patients, including those with loss of consciousness or with dyspnoea, those of advanced age, those with comorbidities, and those who have had prolonged exposure to the tear gas or pepper spray (box).⁴ Medical staff should be aware that there may be particularly serious consequences of exposure, such as respiratory symptoms, bronchospasm, and blepharospasm. Staff should move patients away quickly from the toxic vapours and undress them in a well ventilated area. If contamination is severe, pullovers and T shirts must be removed by cutting and should not be pulled over the patient's head. Contaminated clothes must be sealed hermetically in a double plastic bag.^{4,26}

What is the treatment for people with symptoms of exposure?

How to best manage symptomatic patients is still a matter of debate and is currently based on case series or

SUMMARY POINTS

Tear gas and pepper spray used for crowd control are not without risks, particularly for people with pre-existing respiratory conditions

Pulmonary, cutaneous, and ocular problems can result from exposure to these agents

Treatment for the effects of exposure to tear gas requires chemical decontamination, including protective measures for healthcare staff

Some people are at risk of delayed complications that can be severe enough to warrant admission to hospital and even ventilation support

limited human studies. Eyes should be rinsed for 10-15 minutes with isotonic sodium chloride (0.9%) and any contact lenses removed.⁷ Patients must not touch their face or rub their eyes. Recently, some authors have suggested using air jets to eliminate any remaining particles on the surface of the eye.⁷ For persistent symptoms, experts recommend ophthalmological assessment for abrasions.⁷

Most experts propose systematic washing of affected skin surfaces with soap and water.^{5,7,25} Nevertheless, this strategy remains controversial. Chlorobenzylidene-malononitrile dissolved in water is said to intensify the irritation, and in one small study, skin vesication was observed with 0.5 mg of chloroacetophenone but only when the skin was moist.^{18,26} In a limited randomised study, baby shampoo provided no better relief for eye and skin discomfort than water alone.²⁷ Many decontamination products, such as Diphoterine, are currently being tested for efficacy. However, their cost plus the lack of evidence of effectiveness precludes any proposal for systematic use.²⁸ Severe skin lesions are treated with the same methods as for an acute irritant dermatitis, by using topical corticosteroids and antihistamine agents as necessary.²¹

In the event of pulmonary symptoms such as bronchial spasm, short term medical treatment including oxygen therapy, β_2 -mimetic and ipratropium aerosols may be required.⁷ The rare occurrence of delayed pulmonary oedema in patients with pulmonary symptoms has led to some experts recommending a 24-48 hour stay in hospital for observation or a discharge home with detailed information about potential complications and their clinical manifestations.¹⁸ Digestive tract symptoms (table 2) do not pose a big risk and resolve spontaneously, with the exception of rare cases of voluntary or unintentional ingestion, which requires admission to hospital.²⁹

What are the ethical considerations?

Medical consequences of the use of riot control agents remain ill defined in terms of morbidity and mortality. In 1998 an editorial in the *Lancet* demanded a moratorium on the use of such agents so that the potential long term consequences of these substances

AREAS FOR FURTHER RESEARCH

- The alleged safety of existing riot control agents and of all future innovations in this field
- The delayed toxic effects and potential procarcinogenic risk of repeated exposure
- The effectiveness of decontamination with water (still a matter of debate)
- Development of potential specific treatments and cutaneous therapeutic agents
- Definition of the safety criteria for riot control agents, and discussion of the "rules of engagement" with law enforcement agencies at local and national levels

could be studied further, in particular in the area of carcinogenicity.³⁰

In Europe the medical research necessary to justify the use of certain crowd control technologies is absent, lacking, or of poor quality. Currently, alternatives to crowd control agents seem to be even more deleterious for demonstrators as well as for law enforcement agencies. Whether tear gases are innocuous will nevertheless continue to be debated.

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What's in a name?

William was 80 years old when he was admitted to the ward. Before admission, he had lived a fully independent life, having never been an inpatient before. Now incapacitated, each morning in hospital William was toileted, washed, and fed his breakfast by staff. His condition deteriorated, and he died unexpectedly a few days later.

Conversation with his family revealed that he had been a colonel in the British army and a doctor decorated with the Military Cross for his services on the Normandy beaches during D-day in 1944. In fact, he was known to his closest friends as Ronnie, and by others he preferred the title Doctor. Ronnie was my grandfather, and never before had he been addressed by his first name, William, not even by his own parents as a child.

Shakespeare penned the famous line, "What's in a name?" He implied that a name is not necessarily a true reflection of the underlying person, and as such may have limited meaning. However in health care, I believe a name

is of great importance and may define a person. Illness and the incapacity it brings can strip patients of their dignity. In this era of equality, when addressing patients formally by their surname is disappearing, great care must be taken to ensure we provide patients with the respect they deserve. A name is such a simple word, its correct use can calm and reassure, whereas used wrongly it can strip a patient of what little self esteem and pride remains.

It is the responsibility of all healthcare professionals to inquire as to a patient's preferred name, be that given name, preferred name, surname and title, or otherwise.

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