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## PREVENTION OF CS “TEAR GAS” EYE AND SKIN EFFECTS AND ACTIVE DECONTAMINATION WITH DIPHOTERINE: PRELIMINARY STUDIES IN 5 FRENCH GENDARMES

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□ **Abstract**—Ortho-chlorobenzylidene malononitrile (CS) “tear gas” is a lacrimating riot control agent causing eye irritation, excessive lacrimation, and blepharospasm. Diphoterine® has been efficacious for decontamination of a wide variety of eye and skin chemical splashes and was tested in CS exposure. Five French Gendarmes either entered a standard training CS exposure chamber, developed eye or skin signs and symptoms, and were post-exposure decontaminated with Diphoterine or used Diphoterine as pre-CS exposure prophylaxis in the eyes and on the face before entering the chamber. Gendarmes who entered the CS chamber without prior application of Diphoterine developed expected effects of excessive lacrimation, eye irritation, and blepharospasm. After post-exposure Diphoterine decontamination, in four Gendarmes these effects rapidly resolved and they were fully operational. When Diphoterine was applied to the eyes and face before entering the CS chamber, the expected effects did not occur and the single Gendarme remained fully operational on exiting the chamber. These results suggest that Diphoterine can prevent or rapidly ameliorate the ocular and dermal effects of CS and allow law enforcement personnel to remain fully operational or rapidly regain operational status after decontamination. © 2005 Elsevier Inc.

□ **Keywords**—tear gas; CS; agent CS; Diphoterine; ortho-chlorobenzylidene malononitrile

### INTRODUCTION

Diphoterine® is an active eye and skin decontamination solution that has been tested and safely used for eye and skin splashes with a wide variety of irritant and corrosive chemical compounds, including acids, bases, oxidizing agents, reducing agents, alkylating agents, and solvents (1). It is a polyvalent, amphoteric, hypertonic, chelating compound with six active binding sites for the above types of chemicals. Diphoterine is essentially non-toxic (rat LD<sub>50</sub>s > 2000 mg/kg by the oral and dermal routes). It was not irritating to the eyes of normal human volunteers and rabbits, was not irritating to the skin in rats, and was only a mild skin irritant in a few animals when applied to abraded rabbit skin (1). Its decontamination residues after in vitro reaction with strong acid or base were also not irritating to rabbit eyes (1).

French Gendarmes are required to undergo periodic training involving exposure to ortho-chlorobenzylidene malononitrile (CS) tear gas in an exposure chamber (enclosed space). Because of the known safety of Diphoterine and its reported use in a wide variety of chemical eye and skin splashes, preliminary human volunteer stud-

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ies of its potential efficacy in ameliorating or preventing the ocular and dermal effects of CS were performed in five French Gendarmes undergoing required periodic CS exposure training.

## MATERIALS AND METHODS

Diphoterine, provided by Laboratoire Prevor, Valmondois, France, was tested for its efficacy in decontaminating or preventing the lacrimating and facial skin irritant effects of CS. Five volunteer Gendarmes were exposed to CS during a required periodic training exercise in the same setting and with the same CS exposure conditions as are normally encountered during such training where no prophylactic or decontamination measures are usually made available. The five volunteer Gendarmes were allowed to have post-exposure decontamination ( $n = 4$ ) or pre-exposure prophylaxis ( $n = 1$ ) with Diphoterine as specified below. Amelioration or prevention of ocular and facial skin effects was documented by subject self-report and demonstration of operational status, and was also observed in a non-blinded manner by two of the authors (BV and JB). Volunteer subjects gave verbal informed consent for participation in the studies in accordance with the policies of the study institution.

### CS Exposure Conditions

The CS exposure chamber was approximately  $50 \text{ m}^3$  in volume and the exposure was to a "military grenade F2" containing 150 grams of CS. The calculated exposure was thus to approximately  $3000 \text{ mg/m}^3$  (about 389 ppm). To put this exposure in perspective, the  $\text{ICT}_{50}$  (incapacitating dose for 50% of CS-exposed persons) is  $10 \text{ ppm/m}^3/\text{min}$ ; the U.S. National Institute for Occupational Safety and Health (NIOSH) Immediately Dangerous to Life or Health (IDLH) value is  $2 \text{ mg/m}^3$  (approximately 0.26 ppm) (2). The NIOSH definition of the IDLH is: "The purpose for establishing an IDLH program . . . was to ensure that a worker could escape without injury or irreversible health effects from an IDLH exposure in the event of the failure of respiratory protection equipment . . . As a safety margin . . . IDLH values were based on the effects that might occur as a consequence of a 30-minute exposure." and therefore this typical CS training exposure was *not* expected to be life-threatening or to cause irreversible health effects.

### Post-exposure Decontamination

*Experiment 1.* Two volunteer Gendarmes entered the CS exposure chamber with high concentrations of CS such

as encountered during routine required periodic training when no decontamination measures are usually available. Thus, the only difference from the normal required CS exposure training was that the volunteer Gendarmes were free to elect whether or not to use offered Diphoterine decontamination.

After exiting the CS exposure chamber, the two volunteer Gendarmes had eye and facial skin decontamination done by an unexposed person with 250 mL of Diphoterine from a low-pressure spray container.

*Experiment 2.* Two volunteer Gendarmes entered the CS exposure chamber as described above. Upon exiting the exposure chamber, both volunteers decontaminated their own eyes and facial skin with 250 mL of Diphoterine from a low-pressure spray container to determine if self-decontamination could be done effectively in these conditions.

### Pre-exposure Prophylaxis

Before entering the CS exposure chamber as described above, a single volunteer Gendarme sprayed his own eyes and facial skin with 250 mL of Diphoterine from a low-pressure container. The only difference from the normal required CS exposure training was that the volunteer Gendarme was free to elect whether to use offered Diphoterine prophylaxis or not.

## RESULTS

### Post-exposure Decontamination

*Experiment 1.* When two volunteer Gendarmes entered the CS exposure chamber, the immediate effects were coughing and a suffocating sensation. The CS exposure also resulted in significant excessive lacrimation, conjunctival irritation, reflex palpebral occlusion, and intense photophobia. After developing these signs and symptoms, the two Gendarmes immediately exited the chamber and were decontaminated by an unexposed person with 250 mL of Diphoterine from a low-pressure spray container. There was no increase in irritant signs and symptoms, no extension of the irritated area, and a rapid amelioration of the signs and symptoms of ocular irritation was noted at 4 min after decontamination. At this time, the eyes were open, photophobia had resolved, and normal vision was restored. The facial epithelium was mildly erythematous. At 7 min after decontamination, all ocular signs and symptoms had resolved and the volunteer Gendarmes were fully operational (able to safely fire weapons accurately and perform other normal

duties). Facial erythema had also resolved at 7 min after decontamination.

**Experiment 2.** Two volunteer Gendarmes entered the CS exposure chamber as described above for 2 min. Both developed conjunctival irritation, reflex blepharospasm, and excessive lacrimation and were judged incapable of performing normal duties. After exiting the CS exposure chamber, 250 mL of Diphoterine from a low-pressure spray container was self-applied to the facial skin and both eyes. All signs and symptoms resolved in less than 3 min. No ocular burns, facial burns, or photophobia were noted. Vision rapidly normalized. After medical examination, both Gendarmes were allowed to return to normal duties.

#### *Pre-exposure Prophylaxis*

A single volunteer Gendarme sprayed his face and eyes with 250 mL of Diphoterine from a low-pressure spray container before entering the CS exposure chamber as described above for 2 min. After exiting the exposure chamber, the Gendarme reported no ocular or facial skin irritation, but did have mild coughing. He completely recovered and was able to return to normal duties within a few minutes.

## DISCUSSION

CS "tear gas" (ortho-chlorobenzylidene malononitrile) is a lacrimating and irritant riot control agent that has been used for many years and is generally considered to be relatively harmless when utilized for normal law enforcement activities (3–5). It is not actually a gas, but is rather an aerosol suspension of solid particles. Common, usually short-duration and self-limited effects are dermal irritation, superficial skin burns, eye (conjunctival) irritation, excessive lacrimation, and blepharospasm (4,6–9). More serious but quite rare clinical effects, usually due to exposure in confined spaces or during high-level exposures for riot suppression, have included severe contact dermatitis, sensitization with multi-system hypersensitivity reactions (persistent dermatitis, recurrent cough and wheezing, eosinophilia), reactive airways dysfunction syndrome (RADS), exacerbation of pre-existing asthma, more significant dermal burns, skin ulceration, Quincke-like skin edema, non-cardiogenic pulmonary edema, and pneumonitis (4,6–16).

Diphoterine itself was not irritating in rabbit eyes or in the eyes of normal human volunteers (1). Its decontamination residues after *in vitro* reaction with strong acid or base were also not irritating to rabbit eyes (1).

In law enforcement operations, the most common effects in CS-exposed personnel are excessive lacrimation, eye irritation, and reflex blepharospasm that severely impair vision and thus the ability to be fully operational in emergency situations. The results from these preliminary volunteer CS exposure studies indicate that either pre-exposure prophylactic application or immediate post-exposure decontamination with Diphoterine can prevent or rapidly reverse these incapacitating effects.

When persons who have been exposed to CS are transported in ambulances and evaluated in emergency departments, pre-hospital and emergency department personnel may be secondarily contaminated with CS trapped in the patients' clothing. Diphoterine decontamination of CS-exposed patients before transport has the possibility to prevent such secondary contamination. Pre-hospital and emergency department personnel secondarily exposed to CS might also benefit from Diphoterine eye and skin decontamination.

Based on the preliminary data presented here, Diphoterine may be an efficacious eye and skin prophylactic and decontamination solution for CS exposure and further studies are warranted.

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