THE EFFECTS OF THERMALLY-GENERATED CS AEROSOLS ON HUMAN SKIN

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EDGEWOOD ARSENAL TECHNICAL REPORT

EATR 4075

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January 1967

Task 1C622401A09708

Medical Research Laboratory
Research Laboratories
EDGEWOOD ARSENAL
EDGEWOOD ARSENAL, MARYLAND 21010

FOREWORD

The work described in this report was authorized under Task 1C622401A09708, General Investigations (U) and was partially supported by Deseret Test Center. This work was started in May 1966 and completed in June 1966. The experimental data are contained in case histories 4116, 4119, 4120, 4123, 4124, 4127, 4131, 4144, 4153, 4158, 4174, 4186, 4192, 4206, and 4216, which are maintained in the files of the Clinical Research Department.

The human subjects in the tests conducted by this installation are enlisted US Army volunteers. There is no coercion or enticement to volunteer. The most stringent medical safeguards surround every human test.

Acknowledgments

The authors express their appreciation to Edmund J. Owens, Chief, Aerosol Branch, Toxicology Department, and Ronald Merkey of Aerosol Branch for their assistance.

DIGEST

In order to determine whether o-chlorobenzylidene malononitrile (CS) aerosols, under tropical climatic conditions, offer any threat to the nonsensitized human integument, volunteers were exposed to high concentrations of CS for periods up to 1 hr. Second degree chemical burns occurred in four of the eight subjects exposed to a Ct of 14,040 or 17,700.

It was generally noted that the volunteers most susceptible to sunburn (e.g., blue-eyed blondes as opposed to non-Caucasians) displayed the most severe reactions, even though ultraviolet light was not a factor in out study. It was also noted that the healing of minor woulds (scratches and needly marks) was not affected by the CS burns. Areas covered by fatigue uniform sleeves remained reaction-free in all cases, demonstrating the protective effect of the dry uniform.

It was concluded that:

1. Very high Ct's of CS (~14,000) under tropical conditions of heat and humidity (with moderate wind velocity) produce vesication of human skin.

2. The disability produced by these second degree chemical burns is treatable but may incapacitate the recipient for up to 10 days.

CONTENTS

THE EFFECTS OF THERMALLY-GENERATED CS AEROSOLS ON HUMAN SKIN

I. INTRODUCTION

Direct patch tests of o-chlorobenzylidene malononitrile (CS) powder,[1,2] CS aqueous past,[2] and CS-methylene dichloride solution[1] have demonstrated the primary irritant and vesicant potentials of CS on human skin; however, many chemicals, including some soaps and detergents, will cause patch-test reactions even though they are perfectly harmless in ordinary (diluted) use.[3]

A review of dermatologic complications suffered by CS workers[4] and personal observations in treating such cases reveal a low incidence of direct chemical irritation by CS, in contrast to its high skin-sensitizing potential (antigenicity). In addition, factors such as heat, moisture, and a fair complexion have been implicated in producing or accentuating irritation.[2,4]

When the present study was undertaken, no dermatologic studies of the aerosol form of CS had been reported and no significant skin reactions in workers or volunteers exposed to these aerosols had been brought to our attention. Moreover, human aerosol studies had been made with very low concentrations of CS.[1,5]

In order to determine whether CS aerosols, under tropical climatic conditions, offer any threat to the nonsensitized human integument, volunteers were exposed to high concentrations of CS for periods up to 1 hr.

II. PROCEDURE

Four groups of four medical volunteers each were used in this study. The right arms of the subjects in each group were exposed (figure 1, appendix A*) to thermally-generated CS aerosols (M7 munitions) in a test chamber specially constructed to maintain constant conditions of temperature (97°F), humidity (100%) and wind velocity (5 mph). The CS grenades were fired in a separate chamber, and the resulting aerosol was blown into the test chamber. The grenades were fired in the following sequence:

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* All figures are in appendix A.

1. The first grenade was detonated 1 min. prior to exposure.

2. The second grenade was detonated 7 min. after beginning of exposure.

3. The subsequent grenades was detonated at 10-min. intervals thereafter for duration of exposure time.

Air samples were drawn at periodic intervals during exposure to determine the concentration of CS (figure 2). From these data, the average concentration and Ct* were determined for each of the four groups of men. The exposure time for the groups were 15, 30, 45, and 60 min. respectively.

The left arm of each test subject was exposed to the same climatic conditions and for the smae period of time asthe right arm, but no agent was disseminated during these tests. (The only variation from this procedure was in the 45-min. test group, in which the control arm was exposed for 90 min.)

III. RESULTS

A. Control Arms

The climatic conditions alone produced mild, transient vascular changes in the control arms of most subjects.

1. Symptoms

None

2. Signs

Varying degrees of patchy erythema, which blanched on pressure, could be detected. This slight reticular erythema (livedo reticularis) occurred within 1 min. after the control arm was removed from the test chamber and always disappeared within 15 min. With one exception, no epidermal reaction was noted, the effect being entirely vascular and confined to the dermis. Examination of all control arms for as long as 3 wk. after exposure showed them to be entirely normal.

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* Ct is concentration in milligrams per cubic meter times time in minutes (mg. min./cu.m.)

A thin band of epidermal reaction (persistent erythema and subsequent vesication) appeared 3 in. above the left elbow of volunteer No. 9 (figure 3). This was felt to be caused by persistence of traces of CS powder around the armcuff of the chamber. It should be noted that this volunteer's left arm was exposed for 90 min. In no other instance did this phenomenon occur.

B. Exposed Arms

A spectrum of signs and symptoms was observed when the subjects were exposed to CS. They varied from no significant reaction to severe second degree burns, correlating (to some extent) with the Ct and with the complexion of the volunteer.

1. Symptoms

All volunteers uniformly noted stinging of the exposed forearm, beginning 5 to 10 min. after exposure was begun. Immediately after being withdrawn from the chamber, their arms were rinsed with cold running water for 1 min. to remove most of the white CS powder that visibly clung to the hairs. The stinging increased moderately on washing but subsided within the next 5 min.

2. Signs

Ct's of 4,440 and 9,480 induced an immediate skin response in all except volunteer No. 5, a Negro (table). This began 1 min. after exposure as a patchy vascular dermal erythema, more prominent than that of the control arms. The erythema became confluent, persisted for 10 to 30 min. and produced no discernible sequellae.

Ct's of 14,040 and 17,700 induced a more severe immediate dermal response, which subsided within 3 hr. In addition, a delayed reaction appeared 12 to 24 hr later in all cases; this consisted of first and second degree burns. Both epidermis and dermis were involved, the epidermal reaction predominating. Blistering occurred in four of the eight volunteers in groups III and IV.

Volunteer No. 9, a blue-eyed blonde who sunburns easily, developed the most severe reaction (figure 4). Volunteer No. 15, the other participating Negro, developed borderline (equivocal) vesiculation, which was followed in 4 days with miliaria rubra (prickly heat) (figure 5). In many instances, the sleeve of the fatigue uniform worn by the subjects covered some portion of the upper arm that was in the chamber. These covered areas did not have reactions.

Table. Skin Reactions of Arms Exposed to CS

Average concentration	t	Ct	Volunteer number	Case Number	Immediate erythema (dermal)	Delayed erythema (epidermal)	Vesiculation
mg/cu m	min	mg min/cu m				1° burn	2° burn
296	15	4,440 (Group 1)	1	4,123	+++	- - -	- - -
			2	4,127	+	- - -	- - -
			3	4,144	+	- - -	- - -
			4	4,131	+	- - -	- - -
316	30	9,480 (Group II)	5*	4,124	-	- - -	- - -
			6	4,116	+++	+	- - -
			7	4,120	(±)**	- - -	- - -
			8	Coauthor (RHG)	(±)	- - -	- - -
312	45	14,040 (Group III)	9	4,158	++++	++++	++++
			10	4,119	+++	+++	- - -
			11	4,174	+++	+	- - -
			12	4,206	+++	++	- - -
295	60	17,700 (Group IV)	13	4,153	++++	++++	++
			14	4,216	++	+	+
			15*	4,192	+++	++++	(±)
			16	4,186	++	+	++

* Negro volunteers
** (±) = equivocal

Because of the marked delayed reaction that occurred unexpectedly in groups II and IV, this study was immediately discontinued to preclude serious injury to the volunteer subjects.

3. Treatment

Volunteers No. 9 (figure 4), 13 (figure 6), and 16 (figure 7) who demonstrated the most severe burns, were treated to avoid secondary infection, scarring, or both. The largest vesicles were incised and the subjects were hospitalized for 1 wk, during which time open compresses of cold silver nitrate (1:1000) solution were applied for 1 hr., six times a day.

Volunteer No. 9, who displayed the greatest degree of edema, vesiculation, and discomfort, was also placed on a short course of oral prednisone and overnight applications of bacitracin ointment. Systemic administration of antibiotics was not required. No infections occurred and epithelization took place within 10 days.

Six-week follow-up revealed no sequellae except a mild post-inflammatory hyperpigmentation, which is expected to fade eventually (figure 41). It was also noted that the healing of minor woulds (scratches and needle marks) was not affected by the CS burns.

It whould be emphasized that without adequate treatment, expecially under field conditions, severe local infections would be expected in a large proportion of second degree burns, producing concomitant complications and further incapacitation.

IV. DISCUSSION

It was generally noted that the volunteers most susceptible to sunburn (e.g., blue-eyed blondes as opposed to non-Caucasians) displayed the most severe reactions, even though ultraviolet light was not a factor in our study. This observation raises the question of whether melanin may be a factor in the body's natural protection against chemical irritants. It must be emphasized, however, that no definite conclusions as to susceptibility can be drawn from this limited number of cases.

Areas covered by fatigue uniform sleeves remained reaction-free in all cases, demonstrating the protective effect of the dry uniform. Further studies to devise topical protectants for exposed areas of skin are in progress.

Since this study was done, the fact that accidental burns have resulted when military personnel on maneuvers were exposed to a cloud of CS has been brought to our attention. Ambient environmental conditions when the accident occurred were similar to those maintained in the exposure chamber during the present study. A brief description of the accident is contained in appendix B.

V. CONCLUSIONS

1. Very high Ct's of CS (> 14,000) under tropical conditions of heat and humidity (with moderate wind velocity) produce vesication of human skin.

2. The disability produced by these second degree chemical burns is treatable but may incapacitate the recipient for up to 10 days.

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