J Forensic Sci, Oct. 1972, Vol. 17, No. 4

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Experimental Injuries of the Eye Caused by a Tear Gas Pen Gun Loaded with Ortho-Chlorobenzalmalononitrile

The wounding effects and lesions of the eye resulting from tear gas pen guns and other tear gas devices have been reported recently [*1,2,3*]. The tear gas devices, however, were usually loaded with chloroacetophenone (CN). Recent articles [*4,5*] describe the eye lesions resulting from spraying a solution of ortho-chlorobenzalmalononitrile (CS) into the eyes of rabbits and man. Eye injuries caused by the discharge of tear gas pen guns loaded with CS, however, have not been considered previously, and a review of the medical literature disclosed no reports of injuries of this type.

The purpose of this report is to describe the ocular lesions resulting from the discharge of a tear gas pen gun loaded with CS into the eyes of experimental animals.

Materials and Methods

The tear gas pen gun used in this study consisted of a metal cylinder 10.2 cm in length and 1.2 cm in diameter (Fig. 1). The cylinder has a spring at the rear that has a 3.3-cm-long metal rod attached to the front of it. The tip of the rod is formed into a nipple that acts as a firing pin. A knob attached at the side of the rod is used to cock the device. The knob is drawn backwards to a slot in the cylinder and slipped into a safety notch. The cartridge is threaded into place, and the pen gun is carried cocked and loaded, ready for firing.

The tear gas cartridge is a threaded cylinder, 3.9 cm in length. It contains an Alcan "Maxfire" No. 220 shotgun primer as the only propellant charge. The manufacturer states that each cartridge consists of 50 to 100 mg of CS, which is deposited on three to six grains of colloidal silica dust. The cartridge is sealed with a neoprene sponge-rubber wad, and a thin layer of liquid neoprene is deposited over it and dried. The physiologic effects and certain chemical properties of the chemical agent, CS, are well known [*6*].

Presented at the Twenty-fourth Annual Meeting of the American Academy of Forensic Sciences, Atlanta, Ga., 3 March 1972. Received for publication 31 March 1972; accepted for publication 9 June 1972.

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In conducting the research described in this report, the investigators adhered to the *Guide For Laboratory Animal Facilities and Care* as promulgated by the Committee on the Guide for Laboratory Animal Facilities and Care of the Institute of Laboratory Animal Resources, National Academy of Sciences-National Research Council.

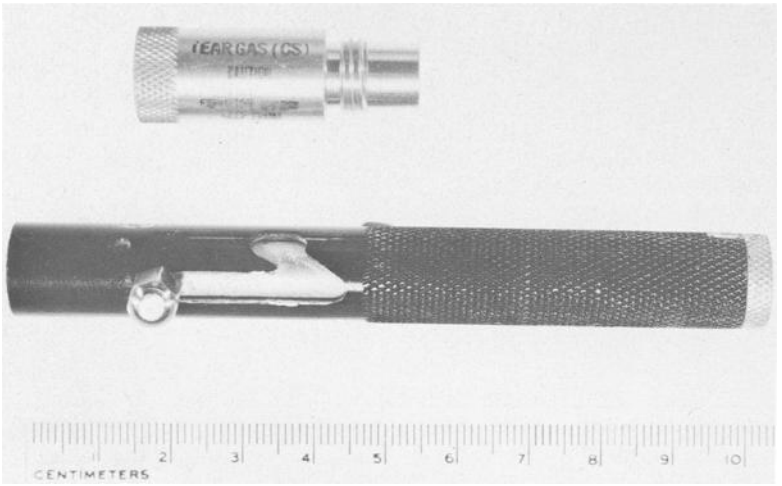

FIG. 1—*Tear gas pen gun and gas (CS) cartridge. (AFIP Neg. No. 71-9120).*

Ten rabbits, ranging in body weight from 3.0 to 3.84 kg, were used in the experiment. Each animal was premedicated with atropine sulphate administered subcutaneously, and anesthesia was induced by the intramuscular administration of a combination of fentanyl and droperidol.[2] When the desired plane of anesthesia was reached, each animal was placed in a vertical position on a restraining board. The left eye was covered by a plastic sheet, and it served as a control. The right eye was exposed by retracting the eyelids with an ophthalmic speculum. The pen gun loaded with CS was then positioned 20.0 cm from the eye and fired.

Immediately after firing, the eyes were examined for damage. Although the eyes were not irrigated or treated in any manner during the study, they were examined daily with an ophthalmoscope, and fluorescein was instilled onto the cornea to aid in the detection of defects.

One of the ten rabbits was killed immediately. Of the three animals exhibiting the most severe ocular damage, one was killed and necropsied one day after the test firing, one seven days, and one 14 days after the test firing. The eyes of these animals were removed and placed in 10 percent buffered neutral formalin. After thorough fixation, the eyes were washed in running water for 4 h and then placed in 80 percent ethanol. Later, they were embedded, sectioned at 6 μm, and stained with hematoxylin and eosin.

Results

Examination of the eyes immediately after firing revealed similar lesions in all, except that the upper eyelid of one animal was lacerated about 5 mm midway along its free margin. Each animal exhibited moderate hyperemia of the sclera and conjunctiva. In addition, there were varying amounts of a mixture of tear gas and silica dust under the eyelids, as well as fragments of the wad. In three of the exposed eyes there were small focal hemorrhages on the sclera and membrana nictitans. All of the control eyes appeared normal.

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One day after the test firing, eyes of six of the remaining nine rabbits exhibited only mild conjunctivitis. In each of the three remaining animals, the eyelids of the exposed right eyes were sealed shut by a yellowish exudate. When the eyelids were parted an abundance of this exudate was found on the conjunctiva and cornea. In addition, there was severe hyperemia and swelling of the bulbar and palpebral conjunctiva. Cloudiness of the corneas of all three eyes prevented the examination of interior structures. In two of these eyes, instillation of fluorescein revealed irregularly shaped, abraded areas on the cornea measuring 5 and 6.3 mm in diameter.

Those eyes that had had only a mild conjunctivitis appeared completely normal after 72 h. At this time, in the two eyes exhibiting severe changes, the conjunctival swelling and hyperemia had diminished slightly, but the cloudiness of the cornea persisted. The corneal abrasions stained less intensely with fluorescein at this time. Seven days after the test firing, the conjunctiva of these two eyes appeared almost normal; only a small degree of redness and swelling remained. The cloudiness of the cornea had also diminished. Instillation of fluorescein revealed decreased staining intensity in the abraded areas. Fourteen days after the test firing, the exposed eye in the remaining rabbit appeared completely normal.

After fixation of the eyes, vertical sections were prepared for embedding. Pathologic changes were observed grossly in these three eyes. Each lens capsule was red, while in the normal eye it was grayish white. The vitreous of the exposed right eye in each animal was yellowish red (Fig. 2); normal vitreous is colorless. In two of the exposed eyes, one or more small blood clots were found in the vitreous.

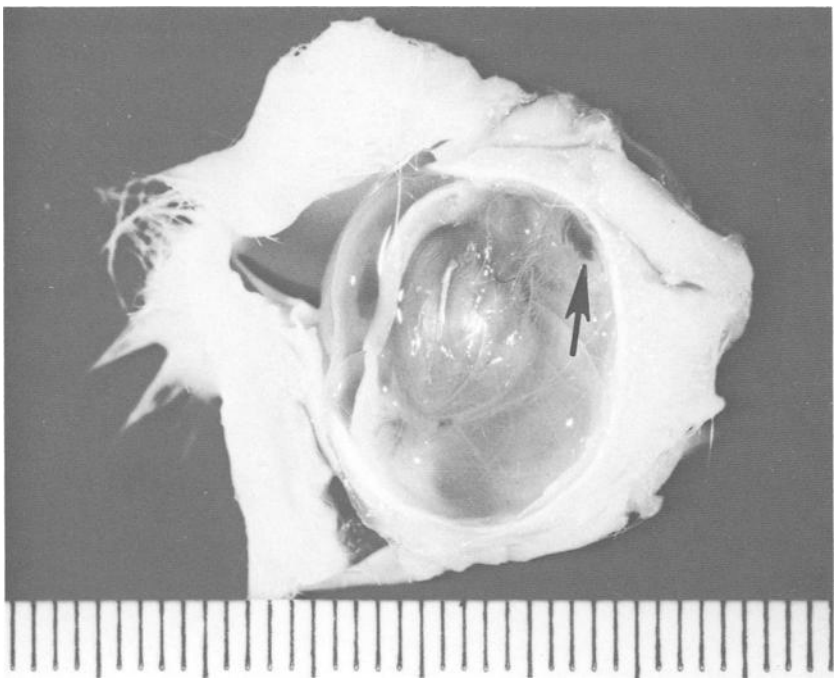

FIG. 2—*Cut section of an eye three days after test firing. Note hemorrhage (arrow) adjacent to retina. (AFIP Neg. No. 72-477).*

Histologic examination of the eye removed immediately after the test firing revealed few alterations. The only lesion noted was disruption of one filtration angle with rupture of many of the epichoroidal and smooth muscle fibers, as well as slight hemorrhage. The control eye appeared normal.

The exposed right eye from the animal killed one day after the test firing, demonstrated a moderate infiltration of the cornea by neutrophils. The cornea was edematous and in one area the epithelium was denuded. The basal layer of the epithelium was diffusely vacuolated, imparting a foamy appearance to this area. There was a small mass of fibrin and erythrocytes in the anterior chamber. Focal areas of hemorrhage, as well as edema of the ciliary processes, were noted. The ciliary body and iris showed scattered lymphocytes and plasma cells. Both filtration angles were increased in size as the result of rupture of many smooth muscle and epichoroidal fibers. In addition, there was an admixture of fibrin, erythrocytes, and neutrophils in the posterior chamber in close proximity to the ciliary processes. The control eye appeared normal.

Similar but more severe lesions were observed in the exposed right eye of the animal killed seven days after the test firing. The cornea was edematous and more densely infiltrated by neutrophils. In addition, the periphery of the cornea was well vascularized. The inflammatory infiltrate and vascularization appeared more severe in the outer half of the cornea (Fig. 3). The vacuoles noted at day two were also seen (Fig. 4). Both filtration angles had been disrupted, and this disruption appeared to be more severe on one side than the other. Fibrin and many erythrocytes, neutrophils, and lymphocytes were present

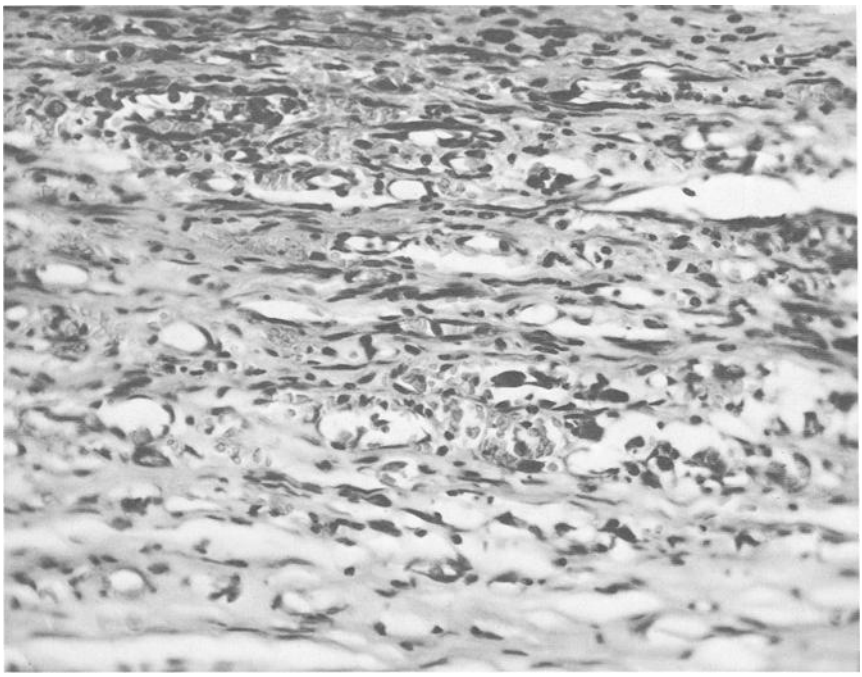

FIG. 3—*Photomicrograph of cornea demonstrates inflammatory infiltrate and neovascularization. Hematoxylin and eosin;* × *350. (AFIP Heg. No. 71-11875).*

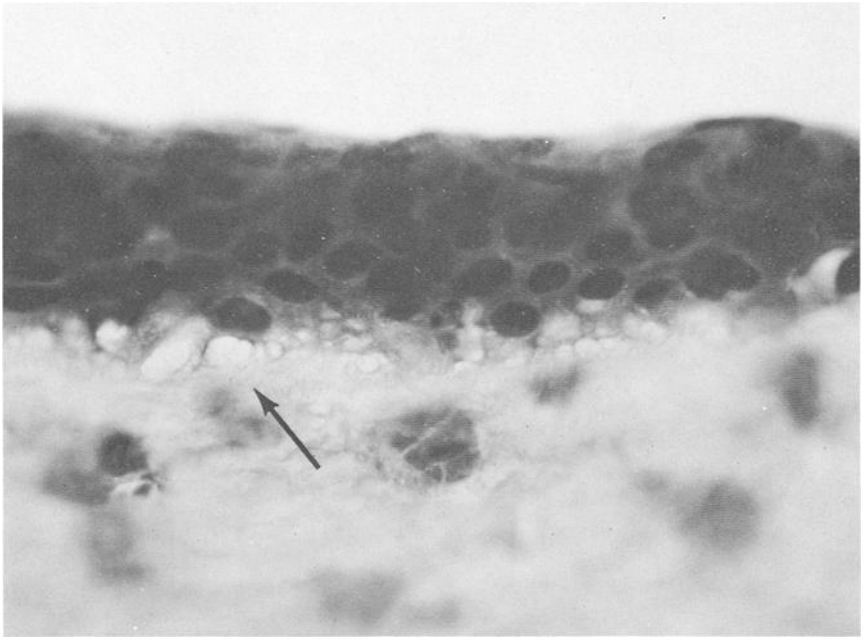

FIG. 4—*Vacuolization of basal layers of corneal epithelium. Hematoxylin and eosin;* × *865. (AFIP Neg. No. 71-11878).*

in the area of disruption (Fig. 5). The ciliary body and the iris were infiltrated by lymphocytes and plasma cells. The infiltrate appeared more extensive than in the eye previously described. There were focal hemorrhages and proteinaceous exudate in the ciliary processes (Fig. 6). Hemorrhage was seen in the posterior chamber in close proximity to the ciliary processes. The control eye appeared normal.

The exposed right eye from the rabbit killed 14 days after the test firing exhibited few alterations. The cornea and both filtration angles appeared normal. There was, however, a sparse lymphocytic infiltrate in this region. The iris and ciliary body were lightly infiltrated by plasma cells and lymphocytes, and there was some hemorrhage in the posterior chamber adjacent to the ciliary processes. In addition, a moderate amount of hemorrhage without apparent organization was present in the posterior portion of the vitreous chamber adjacent to the retina.

Discussion

A previous study of the ballistic characteristics and wounding effects of the pen gun used in this study revealed that, while the velocity of the wad is of a low order of magnitude, it can cause severe injury at close range in experimental animals [*7*]. The wad of the cartridge, the effect of the blast, and the effect of the chemical agent are the three potentially hazardous components produced when the pen gun is discharged. In evaluating the lesions produced in this experiment, each component appears to have exerted certain effects on the eye.

It has been demonstrated that an aqueous solution of CS, when sprayed into the eyes of rabbits and man, will cause a conjunctivitis of about 72-h duration [*4,5*]. The results of

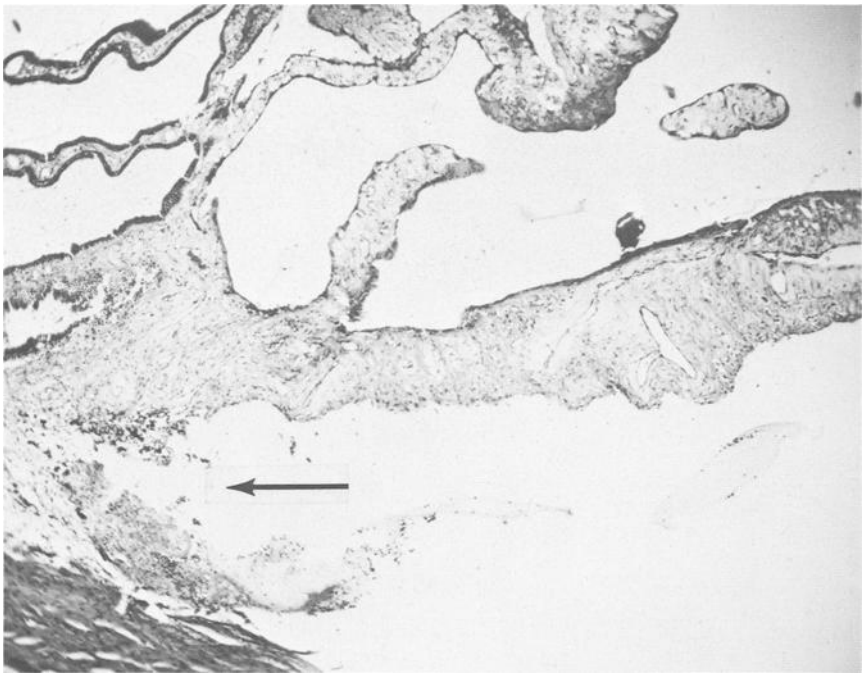

FIG. 5—*Photomicrograph demonstrates disruption of filtration angle (arrow) and an admixture of erythrocytes, inflammatory cells, and fibrin in the area. Hematoxylin and eosin;* × *56. (AFIP Neg. No. 71-11882).*

these studies compare favorably with the results observed in the present study, for conjunctivitis of 72-h duration was the only lesion noted in six of the ten animals tested.

Only three of the animals exhibited severe eye lesions, and this may have been due to variations in individual reaction to a specific traumatic insult. Some of the lesions observed were probably caused by a combination of the effects of CS and the impact of the blast of the pen gun. It has been reported that CS simply sprayed into the eyes produces no histologic change [*4*]. In the present study, however, interstitial keratitis, corneal edema, and vacuolization of basal layers of the corneal epithelium were seen. It is possible that the impact of the pen-gun blast may have caused some CS particles to penetrate the cornea. CS, an irritating chemical agent, could then initiate both the inflammatory reaction and the corneal edema. The vacuoles may have resulted from vaporization of embedded CS particles. Previous reports of wounds by pen guns demonstrated cystic changes in tissue that were attributed to vaporization of CN particles [*1*], and similar changes were seen in human eyes affected by tear gas weapons [*2*].

Probably the most hazardous component is the wad in the cartridge. Impact by the wad or its fragments probably caused the laceration of the eyelid, the corneal abrasions, scleral and membrana nictitans hemorrhage, disruption of the filtration angles, and hemorrhages in the ciliary processes. Some of this hemorrhage may have escaped into the anterior and posterior chambers, and then into the vitreous, imparting to it the yellowish-red color seen on gross examination. The discoloration of the lens capsule may also have been caused by hemorrhage with subsequent absorption of blood pigments.

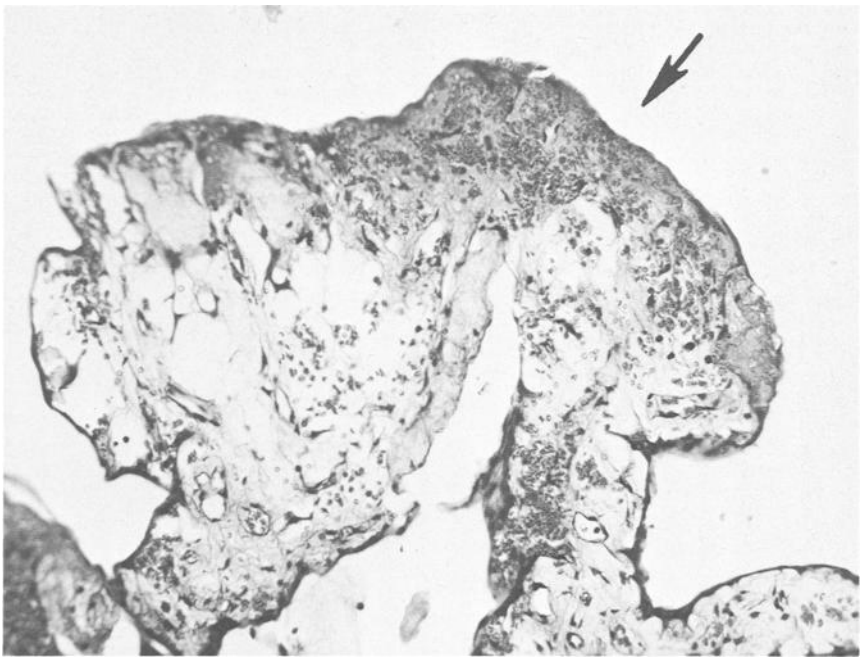

FIG. 6—*Hemorrhage (arrow) within ciliary process. Hematoxylin and eosin;* × *180. (AFIP Neg. No. 71-11884).*

Summary

The eye injuries resulting from the discharge of a tear gas pen gun loaded with ortho-chlorobenzalmalononitrile (CS) into the right eyes of ten experimental rabbits from a distance of 20.0 cm are described. One animal, killed on the day of the test firing, showed minimal pathologic changes. Six animals exhibited only a mild conjunctivitis of 72-h duration without sequelae. The remaining three animals had severe eye lesions, evident on clinical and pathological examinations, including mucopurulent conjunctivitis, chemosis, and clouding of the cornea. In two of these animals, there were large corneal abrasions. The exposed eyes displayed discoloration of the vitreous and the lens capsule, as well as blood clots in the vitreous. On histologic examination, in addition to the intraocular hemorrhage noted grossly, interstitial keratitis, corneal edema, iridocyclitis, disruption of the filtration angles, and hemorrhage into the ciliary processes were observed. These findings confirm the potential hazard of tear gas pen guns when fired into the eye at close range.

References

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