GASES ENCOUNTERED IN WARFARE * †

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The statement has been made that "no powerful weapon of war has ever been abandoned once it proved its power unless a more powerful weapon was discovered. Poisonous gas in World War I proved to be one of the most powerful of all weapons of war. For that reason alone it will never be abandoned (1)." We have all heard many times the arguments against the use of poison gas in warfare. These are founded mainly on what is regarded as its inhumanitarian aspect. This seems to be based on the fact that the Allies in the last war were completely unprepared to cope with the first few gas attacks, with the result that the mortality was high and the men died from suffocation. This provided extremely fertile ground for propaganda directed against the use of gas and toward sharpening public morale which was needed at the time.

Since then a great deal of work has been done, and among those familiar with the subject the feeling is that poison gas, instead of being the vile and treacherous instrument of war which we originally thought it to be, can now be looked upon as one of the most effective and humane. This conclusion seems to be confirmed by a careful study of statistics which has been compiled since the last World War (2). Approximately 24 per cent of all casualties caused by bullets and high explosives resulted in death, whereas approximately 2 per cent of all casualties produced by poison gas resulted in death. It is apparent that a man incapacitated by gas has twelve times as many chances for recovery as one wounded with bullets and shrapnel and other similar missives.

In chemical warfare the term "gas" is applied to any substance whether solid, liquid, or vapor which is used for its poisonous, irritant, blistering, or harassing effects. Usually it is a liquid which volatilizes readily. From a military point of view gases are classified as:

1. Persistent: those that evaporate slowly like mustard gas.
2. Non-persistent: those that evaporate rapidly like phosgene and the tear gases.

From a medical viewpoint, however, poisonous gases have been thought

* Presented before a meeting of the New England Society of Anesthesiology, Boston, Massachusetts, April 14, 1942.
† Released for publication by the Bureau of Public Relations, War Department, Washington.
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of more according to their toxicological actions and have been classified as follows:

1. Lachrymators, e.g. chloroacetophenone, one of the tear gases; used for their harassing effects.
2. Nasal Irritants or Sternutators, e.g. ethyldichlorarsine. Arsenic-containing compounds which promote sneezing and so induce the individual to remove his gas mask and expose himself to more toxic gases which follow.
3. Pulmonary Irritants, e.g. phosgene.
4. Vesicants, e.g. mustard gas.

In addition there is a group of poisonous gases which, although not used for offensive purposes, is frequently met with under conditions of war. These may be called "accidental" gases and are:

1. Carbon monoxide. (Heavy gun fire, mining operations, interior of tanks, burning buildings, internal combustion engines, fractured gas mains.)
2. Nitrous fumes. (Incompletely detonated nitro-explosives form oxides of nitrogen which, with moisture, produce nitric and nitrous acids. Similar in action to phosgene.)
3. Screening smokes.
4. Noxious gases and conditions associated with fire fighting. (Carbon monoxide, carbon dioxide.)
5. Noxious gases associated with chemical fire extinguishers. (Carbon tetrachloride sprayed on heated surface produces phosgene, hydrochloric acid and chlorine. Methyl bromide—common in fire extinguishers—highly volatile, highly toxic.)

The number of poisonous chemical compounds is practically unlimited. They are intimately associated with the coal tar and dye industry. In the last Great War over 4,000 were investigated but less than a dozen were used in actual combat, and only seven were in use at the end of the war. Of these seven there are only two which we are likely to encounter either in the field or as a result of air raids. It is these two which we propose to discuss in some detail as being representative of their groups. They are phosgene and mustard gas.

Phosgene or carbon oxychloride ($COCl_2$) is the most important of the pulmonary irritants. In the presence of moisture it hydrolyzes to hydrochloric acid and carbon dioxide. It can be employed in shells and bombs. With the usual concentrations immediate symptoms may be slight or absent but dangerous symptoms may develop even several hours after exposure. The likelihood of such symptoms developing is much increased if the exposed subject remains physically active. Every person exposed to phosgene vapor without protection of a gas mask, therefore, should become a stretcher case as soon as possible. On arriving in the hospital or at a treatment center, casualties should be grouped into "mild," "moderate," and "severe" categories and, if possible, these patients should be treated separately.

Mild cases show a flushing of the face, increased respiratory rate, and pain in the chest aggravated by coughing. Treatment consists of absolute rest, fresh air, administration of fluids and nursing care, with careful watching to detect any who might develop late sequelae.

Moderate cases show greater respiratory distress with varying degrees of pulmonary edema, cyanosis, distended veins in the neck, and a full, strong pulse without a great increase in rate. Treatment consists of complete rest, continuous administration of oxygen either by nasal catheter or B.L.B. mask. Venesection may be warranted and good nursing care is essential.

Severe cases show collapse, cold skin, pallor, a weak and rapid pulse and no distention of the veins of the neck. There is profuse pulmonary edema, often with froth pouring from the mouth and nose, and great respiratory distress with shallow respiration which is diaphragmatic in character. Continuous administration of oxygen in high concentration by means of a B.L.B. mask and at a rate sufficient to maintain a pink color in the cheeks and lips is indicated. It may be necessary to lower the head and raise the feet to allow the edematous fluid to escape more freely. Morphine should be used cautiously in small doses and only for extreme restlessness. Artificial respiration is contraindicated since absolute rest is essential. Sosnovik (3) has reported that encouraging results have been obtained with subcutaneous injections of oxygen in the treatment of the toxic bronchitis and bronchopneumonia caused by the irritant gases. The immediate effect was stated to be improvement in the subjective feeling followed by diminution of the cough, of the tightness in the chest, of dyspnea, and of the amount of sputum produced, combined with improvement of appetite and ability to sleep. The oxygen therapy appeared to have an analgesic and sedative effect. The initial dose was 200 cc. to 1000 cc. every other day except in frank pneumonia when 1,000 cc. was given daily.

Evacuation to a distant point of patients poisoned with phosgene should be prohibited until they have been pronounced out of danger. Even those slightly affected should be under observation and at rest for forty-eight hours because instances are known (4, 5) in which men who have been exposed to this gas have been able to carry on their work for an hour or two with only trivial discomfort and then have become rapidly worse and passed into a state of collapse with progressive pulmonary edema terminating fatally. In these instances the deficiency of oxygen, probably the result of existing pulmonary edema, had not been felt until muscular exercise increased the need for oxygen.

Mustard gas is dichlorethylsulphide. It was discovered by the German, Victor Meyer, in 1886 but attracted little attention until 1917 when it became known as the "king of the battle gases." It can be employed in shells and bombs and sprayed from airplanes. It is, perhaps, the most important gas for producing casualties in large numbers and yet it has a fatality of only 2 per cent. In the British Army in the

last war 80 per cent of the casualties resulting from it were able to return to active duty within a month. This is an important argument in its favor: It incapacitates but does not mutilate. The early symptoms which develop in the course of a few hours include cutaneous burns ranging from a slight erythema to severe blistering, affecting especially the softer skin and moist surfaces. Other symptoms are blepharitis and conjunctivitis, laryngitis, tracheitis, bronchitis, and vomiting. The lesions may be caused by vapor or actual droplets.

Treatment is preventive and curative: Preventive treatment consists of rapid adjustment of gas masks and speedy and complete removal of all contaminated clothing and of the contaminant from cutaneous surfaces. Cleansing of the skin may be effected by applying an ointment containing bleaching powder. This neutralizes the mustard gas. An alternative method is to scrub with soap and water. Repeated swabbing of the area with gasoline, methyl alcohol, kerosene or carbon tetrachloride is also advised. It must be remembered, however, that these solvents do not destroy the gas but merely dissolve it; therefore, the swabbing must be confined strictly to the contaminated area and the operator must be protected with rubber gloves.

Curative treatment: This is mainly symptomatic. The eyes require early and special treatment and are thoroughly washed with sterile water, normal saline, saturated solution of boric acid or a solution of sodium bicarbonate in 2 per cent concentration. For patients severely injured as well as contaminated with gas, elaborate washing will be out of the question. The clothes should be cut off as quickly as possible and treatment for contamination of the eyes and skin should be carried out as effectively as the patient's condition allows.

Sequelae.—Organic sequelae in those gravely affected are corneal ulceration, bronchopneumonia, and bronchiectasis. In the last war functional sequelae included photophobia, blepharospasm, aphonia, vomiting, and chronic fatigue. It is necessary for physicians to realize that gas poisoning, whatever the chemical irritant concerned, does not of itself cause permanent poisoning of the patient or chronic impairment of his health. Some of the tissues might be rendered more vulnerable to secondary bacterial infection but no special predisposition to pulmonary tuberculosis has been proved (6). It is necessary to insist on this in order to prevent the patient from developing a morbid dread and thereby drifting into neurasthenia and general debility. We all know only too well of the manifold ills and complaints which have been laid to "gassing" in the last war.

Decontamination.—The persistent gases, particularly mustard gas, evaporate so slowly that their vapors can cause severe damage not only hours but days after an attack and it is for this reason that special attention must be paid to the decontamination of clothing, equipment, food and drinking water if they have come into contact with the agent in its liquid state. Persons must be particularly cautious of dugouts, bomb craters, air raid shelters, and damaged buildings which have been ex-

posed to the gas in high concentrations. The British Ministry of Health has formulated plans for a decontamination center (7) which is composed of four essential compartments consisting of an outside room, an inside undressing room, a washing or shower room and a dressing room. The object is to prevent the spread of vapor from the stripping shed onward. The four compartments should, therefore, be sealed off from one another and the doorways covered with wet blankets. The floors should be impervious, preferably made of concrete. Each compartment should have cross ventilation and the stripping room should be above ground level. In the outside room the contaminated person leaves all outdoor clothing. From there he passes through the inside undressing room and shower room to the dressing room. The dressing room opens into the waiting room of the first aid post.

It must be remembered that a person assisting the injured must be just as careful of himself as of the one he is helping. The insidious and penetrative nature of the vapor and the fact that the olfactory senses are dulled by it after only a few minutes make this particularly important. Stretchers require special attention. When not in use they should be kept well under cover because they are difficult to decontaminate if they are once splashed with liquid mustard gas. If they should be contaminated they should be scrubbed with a solution of bleaching powder and later washed thoroughly with water, after which they should be left in the open air as long as possible. The handles may not be safe for contact with the bare hands for several days but this difficulty can be overcome by wearing anti-gas gloves. If the canvas can be readily removed it can be decontaminated by immersing it in boiling water for thirty minutes, by chlorination, or by long exposure to fresh windy air. Clothing can be treated likewise. The English are now using all metal stretchers with wire mesh instead of canvas because of the greater ease of decontamination.

The Gas Mask.—The first improvised mask used during World War I was a cotton pad soaked in washing soda placed across the nose and mouth. Later photographer's "hypo" or sodium thiosulphate was added. This gave fair protection against chlorine which was the only gas used in the early attacks.

It is interesting to note that the late Dr. Karl Connell (1) was placed in charge of the work of developing a gas mask for the American Forces in the fall of 1917 and that he attacked the problem and solved it satisfactorily by methods with which he was familiar in his work in anesthesia. Many advances have been made and now a mask is available with a special canister which will protect against all known toxic gases, dusts, and vapors in the inspired air. The complete gas mask (8) consists of three principal parts—the facepiece assembly, the canister, and the carrier. The canister, perhaps, interests anesthetists most. It consists of a metal box, with an intake valve in the bottom. The air passes through a mechanical filter consisting of fine wire mesh and through certain chemicals. The simplest combination of chemicals

is activated charcoal and soda lime. The soda lime is not for the absorption of carbon dioxide as we use it in our anesthetic apparatus, since there is an exhaling valve in the facepiece; it is for the neutralization of acid gases like phosgene and nitrous fumes. Special combinations of mechanical filters and chemicals have been devised so that they give complete protection against all conditions with the exception of deficiency of oxygen; in this circumstance one must use a mask with a hose leading to an atmosphere where there is sufficient oxygen or else use one with a supply of oxygen provided. Various specialized respirators have been devised. The one which would probably be most satisfactory for nurses, surgeons and anesthetists to wear in an operating room is the optical gas mask since the eye pieces are adjustable and the canister is made to rest in a harness at the lower part of the back of the neck; this prevents interference by the hose with the free use of the hands. They can all be fitted with a special diaphragm in front of the mouth to assist in speech transmission. Assuming proper care, the life of any canister depends upon concentration of the gas, rapidity of breathing and length of time of contact. It rarely breaks down suddenly, but fails gradually. Its user can detect evidences of failure through minor physiological effects and warning signs such as odor, slight headache, and lachrymation. In this connection it should be remembered that no satisfactory mechanical means has been developed for the rapid detection of the presence of noxious gases in the field. Detection depends entirely on the sense of smell and this sense should be adequately trained and developed by the entire civilian population. Mustard gas has an odor of garlic or horseradish; phosgene smells like musty hay. Lewisite, another gas which might be encountered, has a strong odor of geraniums. The only poisonous gas which cannot be detected by smell is carbon monoxide, and it was for this reason that the special all-purpose canister was devised. It affords protection against this gas as well as all others. Its total use should be limited to two hours in order to be assured of its efficiency.

The gas mask is valuable equipment. However it has certain disadvantages. Heat is generated inside the mask especially in hot weather. Resistance to respiration exists. Field of vision is decreased and it is not comfortable to wear for long periods of time.

In case of a gas attack stop breathing until your mask is properly adjusted.

Anesthesia for persons injured by exposure to noxious gas should be limited to regional methods when possible (9). For supplemental anesthesia, it would seem advisable to avoid using inhalation agents and rely on an ultra short-acting barbiturate like sodium pentothal administered intravenously.

It is not known why gas warfare has not been employed in the present conflict, but fear of retaliation may be a very real factor. We can all rest assured, however, that should our enemies decide to use gas, our Chemical Warfare Service is fully prepared and ready to retaliate

with full measure and, more than that, show them a few surprises in addition.

REFERENCES

1. Fries, A. A., and West, C. J.: Chemical Warfare, New York, McGraw-Hill Book Company, Inc., 1921.
2. Gilchrist, H. L.: A Comparative Study of World War Casualties From Gas and Other Weapons, Edgewood Arsenal, Maryland, Chemical Warfare School, 1928.
3. Sosnovik, I. Y.: Subcutaneous Oxygen Therapy for Toxic Bronchitis Caused by Irritating Gases, Sovet. med. (no. 19) 4: 22, 1940; abstracted War Med. 1, 1941.
4. Special Article. Gas Casualties; Their Diagnosis and Treatment, Lancet 1: 613 (May 10) 1941.
5. Special Article. Hospitals and Gas; Reception and Management of Gas Casualties, Lancet 1: 827–828 (June 28) 1941.
6. Medical Manual of Chemical Warfare, Brooklyn, N. Y., Chemical Publishing Company, Inc., 1941.
7. Special Article. Decontamination, Lancet 1: 53 (Jan. 11) 1941.
8. War Department, Washington, D. C.: The Gas Mask, Technical Manual No. 3–205 (Oct. 9) 1941.
9. Hoche, O.: Chemical Injuries and Their Treatment, Med. Klin. 36: 857 (Aug. 2) 1940; abstracted, War Med. 1: 1941.

ADDITIONAL REFERENCES

Eckert-Mobius, A.: Diseases of Upper Respiratory Tract Due to Poison Gases and Their Treatment, Med. Welt. 14: 313 (Mar. 30) 1940; abstracted, War Med. 1: 1941.

Fleming, W. D.: Physiological Effects and First Aid, Conference P. 14, Chemical Warfare Service, Edgewood Arsenal, Maryland.

Fradkin, E. K.: Chemical Warfare—Its Possibilities and Probabilities, International Conciliation, Carnegie Endowment for International Peace No. 248 (Mar.) 1929.

Goldman, L., and Cullen, G. E.: Some Medical Aspects of Chemical Warfare Agents; a Review, J. A. M. A. 114: 2200–2204 (June 1) 1940.

Goodman, L., and Gilman, A.: The Pharmacological Basis of Therapeutics, New York, The Macmillan Company, 1941.

Hessel, M. A.; Hessel, M. S., and Martin, W.: Chemistry in Warfare, New York, Hastings House, 1940.

Ministry of Home Security: Air Raids; What You Must Know; What You Must Do, H. M. Stationery Office, London.

Office, Chief of the Chemical Warfare Service: The Story of Chemical Warfare, Washington (Jan.) 1939.

Porter, W. N.: The Chemical Warfare Service in National Defense, Chemical Warfare Service, Washington, D. C. (Sept. 10) 1941.

Serra, G.: First Aid for Victims of Gas, Gior. di med. mil. 88: 530 (July) 1940; abstracted, War Med. 1: 1941.

Sollmann, T.: A Manual of Pharmacology, ed. 5, Philadelphia and London, W. B. Saunders Co., 1936.

The Medical Department of the United States Army in the World War. Vol. XIV. Medical Aspects of Gas Warfare, Washington, Government Printing Office, 1926.

Underhill, F. P.: The Lethal War Gases, New Haven, Yale University Press, 1920.

War Department, Washington, D. C.: Military Chemistry and Chemical Agents, Technical Manual, No. 3–215 (Oct. 1) 1940.

War Department, Washington, D. C.: Treatment of Casualties from Chemical Agents, Technical Manual No. 8–285 (July 10) 1941.

War Medicine 1: 1941.

Warthin, A. S., and Weller, C. V.: The Medical Aspects of Mustard Gas Poisoning, St. Louis, C. V. Mosby Co., 1919.

White, S. A.: Some Medical Aspects of Chemical Warfare; Chemical Warfare Bulletin 24: 4 (Oct.) 1938, Chemical Warfare Service, Washington, D. C.

Winternitz, M. C.: The Pathology of War-Gas Poisoning, Yale University Press, New Haven, 1920.