WAR WOUNDS AND AIR RAID CASUALTIES

The following article is a supplement to the series of lectures on war wounds and air raid casualties printed in these columns

DETONATION OF HIGH EXPLOSIVE IN SHELL AND BOMB, AND ITS EFFECTS

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PART I

In the official *Medical History of the War*, in order to show how little novelty there is in warfare and to point out that mining dates back to remote antiquity, I quoted an ancient historian who described the use of asphyxiating gas in mining at the Siege of Ambracia in the year 189 B.C. On that occasion the Aetolians filled jars with feathers. These feathers were then set on fire and the resulting smoke blown by bellows into the faces of the Romans. 189 B.C.! Yet the method adopted by the Germans more than a thousand years later was somewhat similar.

In France, in 1917, a group of collieries in the Bethune district was one of the few remaining fields in active operation. Although one of the collieries, Fosse 8, in this very important mine system was in enemy hands, and all the shaft heads and the mining villages of Annequin, Vermelles, Philosophe, etc., had been frequently shelled, the French had been able to continue working. At the height of the submarine menace, when there was an urgent demand for coal by the French, the Germans made a determined effort to stop production in these collieries. Unfortunately the French had delayed building off Fosse 8, which was still used as a downcast shaft. Great quantities of chloropicrin gas were thrown down this shaft. Powerful fans, the modern development of the bellows used by the Aetolians, were installed in one of the collieries. These carried the gas to all quarters of the system, killing many French miners who were at work, and also members of a British tunnelling company who were on guard. The gas was so concentrated as to render respirators useless.

Gas warfare, as it is understood to-day, is the natural evolution of the use of explosives and dates back to the sixteenth century, when gunpowder revolutionized warfare. With its introduction the possibilities of offensive mining in all phases of fortress warfare greatly increased. In the sixteenth and seventeenth centuries gas poisoning from the fumes of exploded gunpowder was of frequent occurrence.

Is Gas Warfare Inhuman?

History shows that every new weapon has met with a hostile reception—inhuman, barbarous, unchivalrous, being common epithets to denounce their use. Among the vast majority of people in this country gas warfare is still regarded as the last word in barbarism. One reason, then, why the use of gas by the Germans raised such an outcry was that it was a new weapon against which there was no defence. It was, moreover, a weapon regarding which there was almost universal ignorance. Very few doctors in this country knew much about gas poisoning and the literature on the subject was very meagre. Everyone knows that by using it the Germans violated the agreement they signed at the Hague Congress in 1899. "The contracting Powers agree to abstain from the use of projectiles the object of which is the diffusion of asphyxiating or deleterious gases." I think it both instructive and interesting to recall a fact which is not nearly so well

known: that the United States was one of the few Powers which did not sign that agreement. In my opinion, educated Americans have a better and more correct scientific knowledge and value of chemical warfare than the British. One of the reasons very properly brought forward by Admiral Mahan, the American delegate, was that the reproach of cruelty and perfidy addressed against the use of gas shells had also been uttered against fire-arms and torpedoes, although both were now employed without scruple. He insisted that

"it was illogical and not demonstrably humane to be tender about asphyxiating men with gas when all were prepared to admit that it was allowable to blow the bottom out of an ironclad at midnight, thus throwing four or five hundred men into the sea to be choked by water, with scarcely the remotest chance of escape."

Those who have had much experience of gas warfare know that of all modern weapons it is the most humane, or, perhaps I should say, the least inhuman, as it causes the least amount of suffering, the smallest percentage of deaths, and by far the greatest percentage of complete recoveries. Proof of this may be obtained from the official medical histories issued by the various combatants in the great war and from standard works on gas and chemical warfare.

In 1937 the Representative Body of the British Medical Association passed the following resolution:

"That this Meeting condemns unreservedly the use of poison gas in warfare as inhuman in its results and degrading to civilization, and relies upon the Council to do everything in its power with a view to securing the co-operation of the medical profession of all countries in order to prohibit the use of poison gas."

As no mention of high explosive shells or bombs was made, the use of these in modern warfare must be considered legitimate and humane. Those who were responsible must have been ignorant of the authoritative sources of information I have given. Perhaps they preferred the work of H. G. Wells. In his book *The Shape of Things to Come* there is the following description of gas warfare:

"The tortures of gas were already many and various, and most of the mixtures then used left tormenting weakness in the system for the rest of life." Further on he declares that "gas warfare ranks in horror with the story of judicial torture or the story of ritual cannibalism, but its inhumanity is more striking because of its nearness to our time."

In his *History of the Next Hundred Years* he describes, most incorrectly, the effects of mustard gas.

"It is doubtful if any of those affected by it were ever completely cured. Its maximum effect was rapid torture and death; its minimum, prolonged misery and an abbreviated life."

After I had finished reading the B.M.A. resolution I read in the daily newspaper that in Cleveland, U.S.A., forty constables dispersed with tear gas 600 strike pickets and their supporters! In France, as early as 1912, lacrimatory grenades had been used by the military in civil disturbances, and Prentiss, in his great work *Chemicals in War*, very pertinently points out:

"No Government can be open to criticism for using against an invading army weapons already employed against its own unruly nationals" (p. 688).

Legitimate Gas Warfare

Few people realize that, with what might be termed the legitimate weapons of modern warfare in which explosives are used, many casualties from gas poisoning occur. During the great war thousands of casualties from gas poisoning were caused by shells, trench mortars, bombs, and aerial torpedoes bursting in deep trenches, dug-outs, cellars, concrete structures, and enclosed places, as well as in ships. Casualties from gas poisoning also occurred from mobile charges used to destroy dug-out systems, from bombs bursting in houses and flooding basements with gas, from the bursting of gas mains and pipes, and from many other causes.

Carbon monoxide was the most dangerous gas encountered in military mining. After a mine was exploded the galleries were filled with gas. In some cases this welled up the shafts and flooded the surrounding trenches, poisoning the occupants. Gas poisoning occurred in gun pits, in closed machine-gun emplacements, owing to the blow back, in tanks from leakage of exhaust, and from the use of coke braziers in cellars, dug-outs, and other confined places. As the official *Medical History of the War* properly states, in all these cases

"the primary object for which the explosive was employed was its destructive effect, and it was to chance rather than to design that one must attribute the deadly effects of the fumes."

When the first Hague Conference was discussing the employment of projectiles, the sole use of which is the diffusion of asphyxiating or deleterious gases, it was pointed out that, when H.E. shells detonated, poisonous gases were generated which might cause death in confined areas. After discussion the Conference ruled that *if the splinter effect of a shell was greater than its noxious-gas effect, it would be regarded as a legitimate weapon, but if the gas effect were greater it should be banned*. That is to say, that allowance was made for the gases which are necessarily produced by high explosive shells. Gas was forbidden, but the most cruel and devastating of modern weapons, H.E. shells and bombs, received the sanction of the Conference. Prentiss very properly points out that the question of what projectiles were permissible within the meaning of the first Hague Conference was never actually put to the test, because, when gas warfare did begin on a big scale, it was not by projectile but by drift gas from cylinders.

Those who have extensive knowledge of the use of gas in warfare are greatly relieved that those in authority have recovered from their obsession regarding the importance of gas attacks from the air. They have now come into line with other countries which regard protection against H.E. bombs as of major, that against gas as of minor, importance. It is therefore much more important to study the use and effects of high explosives than those of gas poisoning, just as it is more important to provide splinter-proof shelters than gas-proof rooms.

High Explosives

In connexion with defence against aerial bombing certain important facts regarding explosives should be known to all doctors.

High explosives depend for their action upon the instability of the chemical equilibrium of their constituents. They consist of compounds of carbon, oxygen, nitrogen, and hydrogen so feebly combined that, when fired by combustion or detonation, new, simpler, and more stable compounds are formed. Once chemical action is started it proceeds with great velocity, and the explosive is immediately converted into gases with the evolution of heat. These gases, now occupying an enormously greater volume than the original substance, have powerful disintegrating properties. High explosives are very violent, detonating at the rate of several miles per second, many

times greater than the most violent hurricane.* In explosives used to propel bullets, shells, etc., the combustion is much slower. The violence and shattering effect of the explosive depend upon the velocity of detonation, which varies in different explosives, and also upon the amount of gas and heat generated. To effect detonation of high explosive a detonator is used, which in its action corresponds to a very violent and sharp blow accompanied by heat and flame.

Generally speaking, explosives contain an excess of oxygen, and, theoretically, should give rise to little carbon monoxide. But they vary much in this respect, and, in the conditions under which they are generally employed, produce considerable quantities of this gas. Shells give rise to less carbon monoxide than bombs or mobile charges. In all of these, if from any cause—deterioration of explosive, insufficient detonators, etc.—the wave of detonation dies out, and a slower form of combustion results, incomplete or partial detonation is said to have taken place. In this event the products of combustion are altered, much more carbon monoxide and, in addition, nitrous fumes being formed.

When a high explosive is ignited it burns at the rate of a few feet per second. During the war explosive salvaged from the enemy and from mines which could not be used was laid out in long lines and destroyed in this way. The products of combustion are quite different from those of explosion or detonation, very large quantities of carbon monoxide and nitrous fumes being formed. Such accidents occurred in the Navy during the war; and, in gold mining on the Rand, several accidents, where stores of explosive underground were accidentally set on fire, have been reported.

Notwithstanding the colossal scale on which explosives were used during the war, no epoch-making discoveries were made, and none have been made since. Nitroglycerine, which was discovered in 1846, still remains the most powerful high explosive. The large number of new explosives used during the war, and others which have appeared since, are merely new mixtures of substances which have been used for many years, some the natural outcome of shortage of certain materials. All the Powers at war, with the exception of Germany, used practically the same types of explosives. The Germans during the latter months of the war used liquid air very extensively as an explosive for demolition work, and for blasting operations in making dug-outs and tunnels. They were also the first to use liquid oxygen for supplying oxygen to airmen at high altitudes.

Very valuable information regarding explosives was gained from the extensive mining operations which were carried out on the Western Front. Never before had explosives been used on such a huge scale. The fact that in 1916 the enemy fired 700 mines and the British nearly 750 will convey some idea of the intensity of mine warfare. For a considerable period 30,000 men were engaged in active mining and in making underground protection for the troops.

It is the same in connexion with chemical warfare as with explosives, for to-day, twenty-four years after the start of this type of warfare, the two most effective gases belong to the phosgene and mustard gas groups. It is necessary to insist that the deadliest gases cannot be used in aerial warfare.

Most people have a very vague knowledge of explosives; this probably explains their easy belief in fantastic stories of the discovery of wonderful explosives of extraordinary power, tales of which are so often circulated by the Press. One recalls the report circulated soon after America entered the war, of a new American explosive, a tablespoonful of which would uproot St. Paul's. After the battle of Messines, when nineteen huge mines containing tons of high explosive were blown, it was amusing to read the statement of one famous correspondent that one pound of ammonal—the explosive used—could blow the

Mansion House to pieces. Tales of a similar kind have appeared at regular intervals in recent years, indeed they are a striking feature of the Secret Service and detective novels so widely read.

Liquid Oxygen and Liquid Air as High Explosives

A few months ago several newspapers harrowed the feelings of their readers by describing the devastating effects of a new bomb which had come into the possession of the Germans and which had been used in Spain. The high explosive in this bomb was liquid oxygen. It was half the weight of other bombs, and its explosive energy was said to be many times greater. What are the facts? This explosive has been in use for many years. It was first used on an extensive scale in the making of the Simphon Tunnel, where operations had been seriously affected and delayed by the dangerous contamination of the atmosphere from blasting by nitro-glycerine explosives. It was found safe to handle, powerful in action, and, except under most exceptional circumstances, did not produce poisonous fumes. Liquid air plant was installed and liquid air was used on a large scale to improve ventilation. After a short trial owing to practical difficulties its use was abandoned.

For a few years before the war the Germans had been using liquid air as an explosive in mining and quarrying. In the later years of the war Germany had available abundant supplies of liquid air from the manufacture of nitrogen, and great efforts were made to render it more practical and efficient. In 1917 and 1918 they used it for blasting in connexion with the construction of mine galleries, dug-outs, etc., and for carrying out demolitions. Towards the end of 1917 I took part in an investigation into its use as an explosive. Most valuable information was obtained from a South African mining engineer, who had a very large experience of blasting with this explosive. Engineers on the Rand have had many bitter experiences of the fouling of the atmosphere underground by high explosives. As the death rate from this among native labour was very high, strict precautions were taken, and in many mines compressed air and liquid air were in constant use to purify the air. The following were the principal reasons for abandoning its use as an explosive on the Rand. The same reasons prevented its adoption by the British during the war.

One great drawback to liquid air as an explosive, even when the cartridges were charged *in situ*, is its variability, the explosive power of the charge depending upon the proportion of oxygen in the cartridge, which necessarily varies from moment to moment. It is therefore less reliable, less efficient, and its results less easily controlled than other high explosives. Another important point is that, although weight for weight liquid air is more powerful than gelignite and other explosives—in other words its explosive energy is greater—with the type of cartridge used, bulk for bulk, it is less powerful. As a result the diameter of the drill-hole has to be twice that required for gelignite, etc. This was a serious drawback to its employment in mining. I understand that Woolwich Arsenal turned it down as useless for propellant work and for bombs.

Inflammable and Explosive Gases from Detonation of High Explosive in Bombing, etc.

The gases from the detonation of a high explosive vary in quantity and in composition according to the quality of the explosive used and also to other conditions. Those generally found are hydrogen, carbon monoxide, and methane (CH_4), all of which are combustible, and, when present in the proper proportion, explosive. Anything which prevents the carbon in the explosive being converted into CO_2 and the hydrogen H_2O will result in large quantities of H_2 , CO , and CH_4 being formed. This

will happen when there is imperfect detonation of part of the charge. Methane is never formed at the time of explosion, but results from the action of hydrogen on the oxides of carbon as the gas cools down. The greater the amount of hydrogen formed the greater will be the proportion of methane.

Explosives containing T.N.T. give rise to considerable quantities of hydrogen and methane. When any of the ammonium nitrate group of explosives are detonated in the open—for example, mobile charges, bombs, etc.—more CO , H_2 , and CH_4 are found than when the explosive is detonated after being tamped. In some of the secondary explosions which I investigated during the war all these gases were present, but in others there was so little CO that canaries exposed to the atmosphere were unaffected.

The tendency of the gases to explode will depend on certain factors: (1) The amount of gas present—the larger the bomb the greater the volume of gas; (2) composition of gases; (3) velocity and density, pressure and concentration, of the gas. The greater these are the greater will be the liability to explode. Where gas is present in insufficient volume or in unexplosive percentage, and is ignited, the flame becomes spent.

The damage done to tunnels or dug-outs systems by the explosion of gases from detonation of high explosive is generally limited to a small area, and will depend upon the force of the explosion, much greater where the tunnels and galleries are narrow, much smaller when they are large. Even when explosives are used on a comparatively small scale in blasting enough gas may be given off to cause an explosion. The following is an example:

In making a deep dug-out in very hard chalk, cheddite was used for blasting. Of the four shots fired two failed to detonate, one detonated imperfectly, and one completely. After twenty minutes had elapsed the men returned to the face to examine the effects and an explosion occurred. Inquiry subsequently showed that in this case the explosive used had been stored for a long time, with consequent deterioration.

During the war attention was first directed to the explosibility of gases formed from the detonation of high explosives. In 1916 a tunnelling company suffered considerable casualties, the officer commanding, another officer, and sixteen other ranks being killed. As this conveys a very good lesson of one of the great dangers of military mining, and an *entirely unknown danger of bombing*, I shall give a short description of what occurred. *Until this disaster was investigated the danger of carrying a naked light into galleries in which gas was known to be present was not appreciated.*

The enemy exploded a camouflet—that is, a mine which did not break the surface or crater. The explosion was not intense and damage done to one gallery was small. It is probable that the mine had been charged for some time and the explosive had deteriorated. At the time four officers and a considerable number of men were in the galleries. There was an order that as soon as an explosion occurred everyone must leave the mine; an attempt was made to carry this out, but before this could be effected a secondary explosion occurred. The two officers near the site of the explosion were killed by the force of the explosion, both showing extensive burns; the sixteen men, who were at a considerable distance from the point of explosion, were killed by carbon monoxide. The mine rescue men were able to save a large number of the men. As a result of this an order was issued that no naked lights were to be used in the galleries till these were proved clear of gas. Electric lights were always to be employed when gas was known to be present.

Bombs and aerial torpedoes on detonation give rise to large quantities of gas, the CO content of which will be greatly increased if part of the charge is imperfectly detonated. Hence when they incompletely detonate in

houses, the occupants of the cellars and basements are not only exposed to the dangers of gas poisoning against which the gas mask offers no protection, but they run the risk of gas explosions and fires. During the war in air raids on cities and towns and villages serious gas explosions and fires occurred and many lost their lives.

The gas thus produced may be ignited by the great heat resulting from the detonation of the bomb, or by incendiary bombs, or by the presence of a naked light. As bombs penetrate deeply before detonating gas may be given off from the ground slowly, and very gradually collect in cellars and basements, to be fired by someone approaching with a naked light; sometimes it may be hours after the bombardment has ceased. In other cases gas has found its way into cellars at a distance from the exploding bomb by passing through fissures that have been caused by the explosion. Serious gas explosions and fires were also caused by the ignition of illuminant gas that had escaped from pipes smashed by the explosion. These explosions may occur during salvage work among the debris, when pockets of gas may be fired.

It is an obvious precaution to make use of electric torches during all operations where gas is suspected, and, after an air raid, never to enter a cellar with a naked light.

THE STRETCHER PROBLEM

BY

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No single item in the equipment of the medical services in time of war is more important than the stretcher. In the Spanish War, as a result of extensive experience, one type was universally adopted for use in the armed services and in the civilian casualty organizations. This stretcher was employed in the field for the primary transport of casualties from the line of fire to the dressing stations. The same stretcher was carried in all ambulances, and was used in the waiting rooms of field and base hospitals and in all medical units connected with A.R.P.

At present there are two main types of stretcher in existence in England. One is the standard R.A.M.C. stretcher and the other is the type recommended by the Ministry of Health for A.R.P. purposes. The fact that the Ministry of Health has recommended a stretcher entirely different from that used by the R.A.M.C. points to the conclusion that the latter was not considered satisfactory; while the fact that the R.A.M.C. has not adopted, and is unlikely to adopt, the stretcher recommended by the Ministry of Health must imply that neither of the two types is entirely adequate. Before describing the stretcher used in Spain it is necessary to point out that stretchers serve three main and two subsidiary purposes. They are used (1) to carry wounded from the field to the ambulance base; (2) in motor vehicles and trains for the transport of wounded to and from hospitals; and (3) in the waiting rooms of dressing stations and hospitals for the interim accommodation and treatment of patients before operation or hospitalization. The secondary uses of stretchers are (a) as sleeping accommodation for medical personnel; and (b) for the erection of huts, shelters, covers, and camouflage in circumstances where no other building material is at hand.

General Specification

Stretchers must have definite qualities, which will now be stated in their approximate order of importance.

1. Stretchers must be as light as is compatible with serviceability.

2. Stretchers must be comfortable. At times patients will have to lie on them for twenty-four hours or more.

3. Stretchers must be robust; they will have to stand up to the hardest wear.

4. After gas attacks stretchers may have to be decontaminated. It is essential to use material which will stand decontamination.

5. Although not much can be done in the way of postural treatment during transport, it is helpful to have a stretcher capable of holding some part of the patient's body in a position of elevation. This is especially important in cases of cranial or thoracic injury.

6. Stretchers must have sufficient clearance to prevent the patient from touching the ground. If a patient is at a sufficient distance from the ground, treatment, such as injections, bandaging, blood transfusion, is considerably easier.

7. Stretchers must be used in motor vehicles, not all of which have been constructed as ambulances. The minimum of structural alteration of the vehicle itself should be necessary before it is adapted to carry stretchers.

8. Stretchers must have suitable attachments for the application of essential splints, such as the Thomas splint.

9. While not in use for the transport of casualties the stretchers will have to be carried by stretcher-bearers from one place to another. It is necessary to make this work as easy as possible. At times only one man will be available to carry such a stretcher.

Need for Standardization

Two essential considerations in the transport of casualties are the prevention of shock and the prevention of further local injury at the site of the lesion. All extra handling of the patient, such as is necessary for the changing of stretchers, increases the danger of shock and of further injury. The ideal to aim at is, therefore, complete and uninterrupted transport of the casualty on one stretcher. At each break in the evacuation journey the loaded stretcher should be exchanged for an empty one, the latter being returned to the previous point by the returning stretcher-bearers or ambulance. Thus the patient will be spared the pain, discomfort, and danger of being moved from one stretcher to another, and much time will be saved in the process of evacuation. Ambulances will be able to return immediately after depositing their casualties and receiving in exchange an equal number of empty stretchers with the corresponding number of blankets. Such a system of relay evacuation is only possible if the same type of stretcher is used throughout the evacuation line. The needs of the armed services and of the civilian population are identical in respect of stretchers, and there is no reason why the same type of stretcher should not be used throughout the country.

If a "universal" type of stretcher is necessary from the functional point of view its standardization is essential from the point of view of production, maintenance, and replacement. The stretcher requirements of the armed forces may be calculated from the presumed ratio of one stretcher to thirty men. For the civilian population the ratio is more variable, but an anticipated figure of 500,000 stretchers at the beginning of the war, going up to 750,000 during the first year, is not an exaggeration. The problem of production on this scale and continuous replacement can only be satisfactorily solved by complete standardization and the timely preparation of raw materials necessary in the construction of these stretchers. It is also desirable that if one of the component parts of a stretcher is irreparably damaged or lost it should be capable of being replaced by another identical part without the necessity for discarding the entire stretcher.

Storage space must also be considered. Stretchers must be produced in peace time and stored, and they must be delivered in such a way that the minimum space is