WAR WOUNDS AND AIR RAID CASUALTIES

The following article is a supplement to the lectures on war wounds and air raid casualties. It completes the series, which will now be reprinted in book form

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

BY

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PART II

When shells and bombs burst in the open carbon monoxide, with its specific gravity of 0.96 (slightly lighter than air), is quickly dissipated, which makes it useless in offensive gas warfare. In deep trenches under favourable (that is, dull heavy) atmospheric conditions, violent and prolonged bombardment may cause a collection of CO high enough to cause poisoning. British, French, and German observers have proved this by finding CO in the blood of men killed or wounded during the shelling and by observing symptoms of poisoning—headache, giddiness, sickness, loss of consciousness—in a number of those exposed. These symptoms were generally regarded by the men as the result of the noise and the shock of shells bursting in their vicinity. Carbon monoxide has also been discovered in the blood of men killed by the bursting of shells which, though close to them, had caused no apparent wounds, and in the blood of men found in a state of shock under similar conditions. This has been confirmed by French and German investigators.

CO Poisoning from Detonation

Before it was generally recognized that CO poisoning in dugouts and in other enclosed places may follow dense salvos of high-explosive shells, cases of fulminant gas poisoning from detonation of heavy shells, used in 1916 on a vastly increased scale, gave rise to the belief that the different combatants were using a new asphyxiating gas. This idea was strengthened by the fact that all respirators then, as now, gave no protection against carbon monoxide. In a German pamphlet, issued as late as 1918, it was found that the enemy felt it necessary to allay fears prevalent among their troops that the Allies were using a new gas. "The use of special poison gas by the enemy—for example, prussic acid—has not, up to the present time, been definitely confirmed. Cases of death attributed to prussic acid are mostly due to carbon monoxide poisoning."

A shell or bomb bursting in or near a confined place produces large quantities of irrespirable gases which may displace the oxygen content of the atmosphere. In those exposed death may occur very quickly from the deprivation of oxygen as well as from the inhalation of carbon monoxide, the action of which, under these conditions, becomes intensified. Indeed, in such circumstances death may be instantaneous. In dugouts groups of men were frequently found dead, overwhelmed by gas before they were able to make a movement. German officers were found dead while playing chess, one dying just as he was making a move. The sole cause of death in those who were found in dugouts at a distance from the burst was carbon monoxide. During the war a writer in the *British Medical Journal*, discussing these sudden spectacular deaths in dugouts, held that in a number "the true cause was the sudden snatching away of the atmosphere pressure in and around the bodies by the voracious vacuum suddenly produced without." The explanation of this will follow later.

Thousands of soldiers have been poisoned by gas from

shells bursting in or near the entrance to dugouts, subways, or cellars, which, under the conditions, ceased to give effective shelter and became mere death traps. Many examples were afforded during the Somme offensive in 1916 and during the French and British offensives of 1917. The following classic examples will give some idea of the dangers:

The Cumont-Mort-Homme tunnel, occupied by the Germans, accommodated brigade headquarters, two battalion headquarters, an aid post, and a kitchen. During the French bombardment both tunnels became crowded with wounded and stragglers from various units. The bombardment blocked all the entrances, and the galleries were flooded with fumes from the high-explosive shells, which asphyxiated most of the occupants, a considerable number of whom died. Six hundred survivors were taken prisoners.

The Tunnel Cornillet, held by the Germans, was composed of three galleries each a thousand feet long and eleven feet broad. There was an exit from each gallery. Ventilation was obtained from hand fans and from a number of ventilating shafts in the roof. There was accommodation for three battalions. During the French attacks salvos of shells bursting near the entrances, already sealed by the explosions, gassed the pioneers and prevented them freeing the entrances. Next day a large shell penetrated the tunnel doing great damage, and another came through the ventilating shaft. Many of the garrison were poisoned by carbon monoxide, and a large number died. The rest were so demoralized that no attempt was made to clear the entrances. Many prisoners were captured. In this case very few deaths were caused by direct violence. The vast majority were the result of gas poisoning.

How Such Accidents were Prevented

In modern trench warfare and aerial warfare adequate underground protection is all-important. The British defence on Givenchy Ridge in April, 1918, forms an excellent example of how the effects of intense shell fire on dugouts may be combated and supports Professor Haldane's plea in *A.R.P.* for deep underground protection.

Several attempts were made by the enemy to capture the Ridge, each attack being preceded by heavy shelling, which, however, failed to crush the entrances to the deep dugouts. Three of the entrances were protected by ferro-concrete monoliths, each with a minimum thickness of four feet; one entrance was in a cellar strengthened by rails and a bursting course, and three other entrances were covered by elephant shelters with a triple course of rails and five feet of broken bricks as a bursting course. Gas, either from explosives or from gas shelling, was prevented from gaining admission to the dugouts by efficient gas curtains and gas doors. The troops were thus perfectly safe, as was abundantly proved by the success of the counter-attacks which cleared the enemy off the high ground.

Gas from the detonation of shells, bombs, mobile charges, minenwerfers, etc., has been known to gain an entrance into cellars and dugouts at some distance from the burst through fissures in the strata or through cracks in the walls of the buildings. In an intensive bombardment by heavy shells or by bombing, the ground in the affected area may become saturated with gas. This is more likely to occur if there has been imperfect detonation of the explosive, or if heavy shells and bombs with time-fuses have penetrated so deeply that when detonation occurred no craters formed. In all these cases gas may find its way into cellars, basements, or dugouts by percolating through the porous ground or through crevices formed in the ground. It is well to remember that when

gas percolates through soil it loses its distinctive odour and becomes all the more insidious.

On the Western front hundreds of deaths from CO poisoning resulted from the detonation of mobile charges used for destroying dugouts and subways. The following is a good example of what happens, and it also shows the great value of efficient rescue work.

Preliminary to a hostile raid there was an intense bombardment of the British front line trenches. The ventilation of the infantry tunnel was seriously disturbed by the detonation of minenwerfers which crushed in two of the entrances. Shortly after shelling stopped the entrance to the shaft leading to the tunnel was blown in by a mobile charge brought over by the enemy raiding party. A demolition charge of our own which was in the shaft mouth was fired by the action of the enemy charge. Of thirty-six men who were in the tunnel, twenty-five lost their lives by CO poisoning before they could be rescued. Mine-rescue men with apparatus were quickly on the scene and succeeded in rescuing and resuscitating eleven men, all of whom were unconscious and seriously affected. All these men required oxygen, most of them artificial respiration. In two cases oxygen administration was kept up for ten hours. All recovered. The enemy mobile charge which detonated our charge at the shaft mouth had given rise to large quantities of gas.

It is well to remember that very often more gas is given off when explosives in large quantity are fired in the open than when the explosive is fired after being properly tamped. The fact that ventilation, owing to the entrances having been previously crushed in, was defective would accentuate the action of CO, and the presence of even small percentages of CO would, under such conditions, have serious consequences.

Many cases similar to the above were caused during the frequent British raids on the enemy lines, the tunnellers, who accompanied the infantry, carrying over very heavy mobile charges of high explosives. Owing to the high concentration of CO in these cases, and to the difficulty of setting up good ventilation, the entrances having been destroyed, death would follow very quickly. In some places where there was incomplete detonation of the charges, nitrous fumes as well as CO were formed.

Cause of Death in Concrete Shelters subjected to Heavy Bombardment

Recently questions have been asked regarding the effect on the occupants of concrete shelters of severe concussion from the detonation of bombs. Although aerial bombing, owing to the considerable intervals between bursts, is entirely different from intensive bombardment by shells, it is interesting to recall some experiences during the war.

The nature of the ground on Messines Ridge, where there is a water-bearing sand about twenty feet below the surface, made the construction of dugouts impossible. Ferro-concrete shelters were therefore used and proved of the greatest value in resisting shell fire. A large proportion escaped serious damage, although the entrances were blocked. It is very questionable if the occupants of these concrete shelters could remain in a condition able to fight, or even to survive under repeated concussion from the bursting of heavy shells. It was quite common to find the occupants dead in shelters which had been hit, but not penetrated, by eight-inch shells. In these cases there was no question of gas. A number of these shelters in the village of Messines were practically intact, and yet the wood lining and everything inside was shattered into many pieces, showing that the concussion must have been terrific. Anyone who has experienced, as I have, machine-gun fire in a "pill-box" knows the painful effect the concussion has on the ears, and this would be many times less than the effect of heavy shells landing. *Commotio cerebri* would be caused by the intense vibrations being transmitted through the bony structures to the central system. Various methods were adopted to

lessen the intensity of the shock, but without success. After their painful experience at Messines and Langemarck it was quite common for the enemy to leave the pill-boxes during heavy shelling and get into neighbouring shell holes, returning to the pill-boxes when the barrage lifted.

Immediate Effects of Detonation of High Explosives

It is very necessary to understand what happens when a large shell, trench mortar, bomb, or mobile charge explodes. Before considering this I should point out one great difference between shells and bombs or mobile charges. The high-explosive content of a projectile from a gun is greatly reduced by the thick walls of the shell which are necessary to withstand the shock of discharge. The mobile charge or the bomb, on the other hand, is nearly all high explosive.

When a charge of high explosive is detonated there is, first, an enormous expansion of gas. This is referred to as expansion, or explosive wave, or simply as blast, and corresponds to the French "*vent du projectile*." This is followed by another wave, a tremendous inrush of air, which has been variously described as recoil, suction, or aspiration. Sir Frederick Mott, from the various pathological findings, refers to the first as the wave of compression, and to the second as the wave of decompression. Some observers hold that the latter has even greater destructive action on the human body than blast.

It is not necessary in this article to describe the extraordinarily varied effects of bombing on buildings in cities and towns. This has been very vividly described and minutely detailed by Professor J. B. S. Haldane, John Langdon-Davies, and other writers from their recent experiences in the Spanish War. In order to illustrate the two explosive waves, let me quote Professor Haldane

Diagram of the Effects of an Explosive Wave

Note.—The size of the zones A and B will depend on the amount of explosive in shell or bomb.

in his most interesting and informative work, *A.R.P.*, which I advise all doctors to read. He describes how, when bombs burst in a Spanish street, the metal shutters of shops which had not been knocked down were sucked outwards, and when a bomb fell inside a house a large part of the shattered walls fell inwards.

By far the greatest number of casualties resulting from detonation of heavy H.E. shells and bombs is caused by flying pieces of shell, brick, stones, and debris, which are impelled at great velocity and may cause death hundreds of feet from the exploded bomb or shell. A considerable percentage of the casualties are caused by crushing, by burying, and by asphyxiation from the collapse of buildings, entrances to cellars, dugouts, etc. Inside the zone of maximum violence bodies may be torn

to pieces and mutilated by the force of the explosion. Men may be hurled by the force of the explosion and smashed against buildings or against the ground.

Wounds produced not by missiles but by the explosive waves may be produced (a) from without inwards, this due to the enormous compression and velocity of the gases (the explosive wave travels many times faster than the fiercest hurricane), or (b) from within outwards, during the recoil.

To give some idea of the intensity of the blast, Sir Frederick Mott, in his book *War Neurosis and Shell Shock*, quotes the American Medico-Military Report, which stated that an "aneroid showed that the explosion of one of these shells caused a sudden atmospheric depression of about 350 mm. of the mercury tube, corresponding to a dynamic pressure of about ten tons to the square yard."

There is no doubt that many cases of sudden death, where no wounds were found, were caused by the severity of the blow over the heart or epigastrium. Sir Frederick Mott believes that the enormous aerial compression "may be transmitted to the fluid about the base of the brain and cause shock to the vital centres of the floor of the fourth ventricle, causing instantaneous arrest of the function of the cardiac and respiratory centres." This, he held, explained many of the cases of sudden death where there were no visible injuries to the body. In describing a personal experience of his own during the war when he was in the vicinity of bursting shells Professor Haldane thought that death in some similar conditions might be due to paralysis of the breathing.

The second, from within outwards, explains the bursting open of cavities as well as the extensive and strange character of the wounds occasionally noticed in the vicinity of explosions. After the bursting of large shells, bombs, and trench mortars near dugouts or cellars, the parts of the body which would be affected by the suction are those which contain gas, and one would expect to find conditions similar to those produced in accidents in caissons but more exaggerated.

Langdon-Davies, in *Air Raid*, describes how many bodies were found which did not bear a mark of any wound. Mitchener and Cowell have also described similar casualties caused by bombs exploding in narrow streets. On post-mortem examination the lungs were found to be torn and the abdominal viscera ruptured. Early in the great war Adrian Stokes, the famous pathologist, described to me extensive haemorrhages in the lungs with no visible wounds. In the official *Medical History of the War* (vol i, p. 46), in describing the effect of a trench mortar bursting near a signal dugout in which two signallers were working, the contributor stated that

"nothing more was seen of either of these men except one of the lower extremities, which was hanging on the German wire about 150 yards away. It had been disarticulated at the hip-joint. The number of men who have completely disappeared during the war, and whose deaths have had to be presumed, suggests that these disruptive effects are by no means rare."

As I have already pointed out, a number of the deaths of occupants of dugouts, especially of those at a distance from the burst, were due to CO. This gas is most insidious in its action. A good example of this was afforded when, during the work of clearing the ruins in Ypres, the bodies of forty British soldiers were discovered in cellars in the Grande Place. Some of the bodies were badly mutilated; those in other parts of the cellar were lying in peaceful attitudes, obviously poisoned by the fumes from the detonation of a large shell.

In experiments carried out in France to discover the effect of detonating 20-lb. charges of ammonal in dugouts, dogs were placed in various positions in these dugouts.

Those within the zone of maximum violence were blown to pieces or killed outright by the force of the concussion without showing any injuries, while at a distance some were killed by CO and others seriously affected by it. This is very similar to experiences in the trenches when canisters of high-explosive demolition charges were used to drive out the occupants of dugouts.

Although I have pointed out some of the dangers of shells, bombs, and mobile charges bursting in or near dugouts, cellars, buildings, etc., it must be remembered that in modern warfare life would be impossible without adequate underground shelters, and that these undoubtedly saved many thousands of lives during the great war. In an article in the *Spectator* in February, 1939, I pointed out that

"the experience of the war and recent experiences in Spain proved that nothing so quickly gives confidence and allays panic in heavy bombardment by high-explosive shells and bombs as the provision of efficient underground shelters. The imperative duty of the Government is the adequate provision of large underground bomb-proof shelters in those cities and towns which are likely to be attacked. Underground accommodation for hospitals on a large scale should be commenced at once. The bombing by the Germans during the war of the crowded hospitals at Etaples may be remembered by many. I saw the ghastly results. Hundreds of the patients, doctors, nurses, and staff were killed or wounded."

These opinions, I may add, have in no way been affected by the last authoritative pronouncement on the subject, which rejected deep underground protection against bombing as unnecessary and undesirable, as well as being economically impossible.

OCCUPANCY TESTS OF AIR-RAID SHELTERS

"To every action there is an equal and opposite reaction." Thus the provision of air raid shelters for all follows on indiscriminate bombing by aeroplane. It is with a sense of relief that we have read the report of some detailed occupancy tests of shelters for factory workers.¹ Such a research indicates the standard of our preparedness. The tests were carried out between April 19 and May 22, 1939, by Messrs. J. and E. Hall, Ltd., in collaboration with some members of the medical profession and the Department of Industrial Physiology, London School of Hygiene and Tropical Medicine.

Shelters for Factory Workers

The shelters employed are of sufficient number and capacity to accommodate the whole staff of approximately 1,700 people. Two types of shelter are adopted—one of steel, completely below ground level, and the other of pre-cast concrete, only partly below ground level. The steel shelter is a standard shelter twenty-seven feet in length with a concrete floor five inches thick. The steel is surrounded by six inches of concrete, the topmost part of which is 1 ft. 9 in. below ground level. It is entered by means of a concrete stairway, through a gas-tight door at one end, and an alternative exit is provided at the other end by means of a gas-tight trap-door reached by a step-ladder. The pre-cast concrete shelter, which is also twenty-seven feet in length, has its concrete floor approximately five feet below general ground level, and the slabs of concrete above earth level are covered with two feet of excavated earth. Both shelters have seating accommodation for fifty occupants, and they are comfortably fitted out with, among other things, electric light, wireless installation, and telephonic communication. The gross cubic capacity per person when full is 24.2 cubic feet

¹ *Report on Occupancy Tests of Air Raid Shelters for Factory Workers*. (Pp. 27; 3 folding diagrams. 2s. net.) London: H. K. Lewis and Co.