SHOCK, EXHAUSTION, AND RESTORATION IN WAR

GEORGE CRILE, M.D., OTTO GLASSER, Ph.D., and DANIEL P. QUIRING, Ph.D.

The word shock is not scientific. It expresses neither the state of the patient nor the cause of his condition. The term is ordinarily used to denote a state of physical exhaustion which has been rapidly developed by traumatic, toxic, or thermal stimuli. But if a soldier with a crushed toe limps in an imperative retreat for several days in pain and distress, without food, drink, or sleep, and is finally found prostrated, is he in shock or exhaustion, or both? Can the most complete microscopic and clinical study determine the cause of his death? Even when there is a paramount cause, it can hardly be dissociated from other factors. There is probably no ultimate difference between the bloodless, intangible causes of exhaustion and the bloody, tangible causes of shock. These states have interchangeable values; they depend on some common biologic principle. When the mechanism of fatigue and exhaustion is understood, the mechanism of shock will be understood.

Shock presents a special problem in war, since soldiers are commonly subjected to factors causing depression and exhaustion. Contributing factors are intensely exciting emotions such as fear; extreme physical exertion as in forced marches; loss of sleep; hunger and thirst; excessive heat or cold; and physical injury involving great pain and loss of blood.

Although the state of shock is difficult to define, some of the forces that control shock—the forces that control life and death—can be measured and expressed in physical terms. A physical phenomenon constantly associated with living processes is the potential gradient between various parts of the living organism, notably between the brain and the heart, or between the brain and the liver.

The potential gradient between the brain and the liver, the brain and the blood in the left ventricle, or indeed the brain and any other organ or tissue of the body, can be accurately and continuously measured in experimental animals and expressed in millivolts.[1] Hence the normal power of an animal can be expressed in millivolts, and likewise the degree of excitation, depression, or exhaustion from any one, or any combination of factors which may affect a soldier in war. The potential gradient may also be considered an index of the factor of safety of the animal at a given moment—that is, an index of the amount of energy that can be drawn upon until death occurs.

In experiments on 503 animals, with and without the use of anesthesia, we tested the effects of gunshot wounds, hemorrhage, and other physical injuries on various organs and tissues. We also used various depressing and stimulating drugs. In all these experiments death was found to coincide with the fall of the potential gradient to zero.

But a sharp distinction must be made between the two types of factor causing definite change in the potential gradient. A decrease in value is associated with (1) mechanical interference with the normal functioning of the organs of the experimental animal, or (2) a gradual decrease in the normal organic functions. An example of the first type is sudden momentary stoppage of the heart by interference with the superior laryngeal nerve or by direct injury of the heart; in such a case the gradient falls abruptly. A factor of the second type is continuous, prolonged trauma, hemorrhage, infection, loss of sleep, or intense emotion, causing an equally deep but gradual depression of the potential gradient. Any one or any combination of these factors may reduce the vital potential gradient to zero.

There is an important histologic difference between the effects of sudden and of prolonged depression of the body. This difference was observed in the cells of three organs: the brain, the liver, and the adrenal cortex. After sudden inhibition of circulation, respiration, or activity of the brain or medullary centers, postmortem microscopic examination showed no change in the cells of the brain, the liver, and the adrenal cortex. But after gradual exhaustion, over hours or days, by such factors as hemorrhage, pain, or loss of sleep, there were striking cellular changes in the brain, the liver, and the adrenal cortex.

Extensive study of these cellular changes has been reported.[2] The investigation included both wild and laboratory animals, as well as soldiers who had died from the stress and injuries of battle. In research extending over 9 years no physical changes were found in any muscle cell, voluntary or involuntary, though the muscular system constitutes the greater part of the body and takes the largest share in physical effort. Nor were there cellular changes in other ductless glands, abdominal viscera, lungs, fat, connective tissue, red blood cells, or bones. They occurred only in the brain, the liver, and the adrenal cortex.

Another series of experiments was undertaken to measure changes in the electric conductivity, electric capacity, potential gradients, and temperature of the brain, the liver, and the adrenal cortex under many types of stimulation and depression.[3] The changes in the electric conductivity, electric capacity, potential gradients, and temperature of the brain, the liver, and the adrenal cortex paralleled the histologic findings as well as the degree of excitation, depression, and exhaustion of the subject.

It appears that the potential gradient between the brain and other parts of the body plays a vital role in the life and death of an animal. In our experiments the brain had positive polarity as compared with the liver and other organs of the body. This may mean that in the brain large numbers of positive ions are formed, which travel from the positive pole to the negative pole. However, the negative polarity of the body must be further explained.

There is a cell bearing the shape of a biconcave disk which possesses no nucleus in man and most other mammals, and exhibits very little metabolism. This cell, through its tumbling and the movement of the blood stream, is subjected to constant friction in the body. It is covered by a lipoid film approximately 1/2,500,000 cm. in thickness.[4] This cell is the red blood cell. It is ideally evolved to accumulate static electricity. The negative static potential depends on the speed of the blood flow, which in turn is regulated by the force and frequency of the heart beat.

There is a certain analogy to the bipolar plan of the living body in a copper-zinc electrolytic battery. Here most of the chemical energy of the battery is gained at the negative pole, while the positive pole produces positive ions through oxidation. The positive and negative ions in the battery balance each other. As the positive ions travel to the negative plate, causing the negative plate to perform chemical work, so the positive ions of the brain and the rest of the central nervous system travel to the negatively charged organs and tissues, causing them to perform their work.

When current is drawn from a Volta liquid battery, polarization occurs. If the flow of current is stopped, the battery recovers as depolarization takes place. A similar phenomenon takes place in tissue cells. If current is drawn from the cells, polarization occurs which manifests itself in fatigue, exhaustion, and eventually death. If the final state is not reached, and if the tissue cells are permitted to recover with sufficient rest, depolarization occurs and the body recovers.

With the complete, irreversible polarization of death, when the potential gradient is at zero, the changes that occur in the cells of the brain, the liver, and the adrenal cortex are at their maximum. But when depolarization occurs, as after a period of sleep, the overwhelming microscopic changes in the cells disappear as if by magic. Equally, when the energy of the animal is again restored, do the electric conductivity, electric capacity, and potential gradients return to normal.

During one series of experiments 84 rabbits were kept awake continuously[5]. Though they were given food, drink, and comfortable surroundings, death from loss of sleep occurred on the average in 92 hours. If in addition to being kept awake rabbits were subjected to fear, injury, or intense conscious activity involving the energy systems—to intense stimulation of the brain, the liver, the adrenal cortex, and the heart—then exhaustion and death occurred within a few hours. The physical changes noted in the brain, the liver, and the adrenal cortex were identical with those produced by mere loss of sleep. That is to say, abnormal excitation, injury, and stimulation produced polarization of identical type but in a shorter period than uninterrupted maintenance of a conscious state.

As already explained, the brain possesses positive polarity as compared with the negative polarity of the liver, the blood, and the rest of the body. We believe that this conception explains the nature of shock and therefore the rationale of its prevention and treatment. When the brain is protected by nerve block, by gentle operation, by light anesthesia, by maintenance of normal temperature, the positive pole of the bipolar mechanism remains normal. On the other hand, when hemorrhage is immediately repaired by transfusion of whole blood or blood plasma, when the force and frequency of the heart beat are kept within normal range, then the negative pole is kept within the normal state. If both the positive and the negative potential are maintained, then there is a normal potential gradient. That is to say, life continues normally; shock is avoided.

In accordance with these principles has been developed the shockless operation and the modern treatment of shock in war and civil life. The following measures are most effective in the problems of surgery, whether in war or peace.

Pain should be relieved by adjusting painful dressings, splints, or tourniquets and arranging for maximum comfort. If pain cannot be relieved by other means, morphine should be given unless there are intracranial injuries or cyanosis is present. The body should be tilted with the head down.

The fluid balance should be established. In serious cases whole blood or plasma transfusions should be given. Lost body heat should be restored by blankets, hot air, or hot water.

In the effort to restore the depressed energy, measures that lead to further exhaustion and shock are sometimes employed. Any drug that can act as a stimulant can further deplete the bodily energy. The overactivated soldier needs the opposite of stimulation, namely negativity. Interference with physiologic rest is interference with repair; therefore, no stimulants are to be used.

Local, regional, or spinal anesthesia, alone or supplemented by light inhalation anesthesia, is preferable to use of the heavy anesthetics, such as ether or chloroform. If the heavy anesthetics are necessary, anesthesia should be as light and short as is consistent with good surgery. Operations must be done deftly, quickly, and with a light touch.

The restorative power of warmth, food, drink, comfort, and rest cannot be overemphasized; but the most potent reparative agent in exhaustion and shock is deep, untroubled sleep. Comfort, quiet, and assurance are beneficial in large part because they lead to the deep polarization of sleep. This is attested in the intense phases of war. Soldiers sleep in trenches, in mud, on stones, in rain, under bombardment. They sleep in shell holes, on the march, and on horseback. They sleep with compound fractures or abdominal perforations; they sleep despite pain and hunger and thirst; sleep though captured; sleep on stretchers awaiting operations. When at last in a comfortable bed, an exhausted soldier may sleep heavily for two days. Once the desire for sleep has been satisfied, the soldier has wants, appreciates pain, experiences hunger and thirst. The shrunken face fills out, exhaustion is relieved, normal life is restored.

SUMMARY

Although the modern treatment of shock is increasingly effective, the mechanism of shock is not thoroughly understood, and the word itself is loosely and unscientifically employed. Shock may be defined as an extreme stage of exhaustion—as the severe diminution or derangement of the forces that maintain life.

The understanding of shock may be clarified by the conception of the body as a bipolar mechanism. According to this view, the brain is electrically positive as compared with the rest of the body. The blood, the liver, the heart, and all other organs and tissues have negative polarity with reference to the brain and the rest of the nervous system. This may be explained by oxidation in the brain, which produces posi-

tive ions, and by charge-up of the red blood cells in the heart with static negative electricity.

A potential gradient exists between the brain and the rest of the body. This has been demonstrated in experiments on 503 animals. It was found that under various stimulating, depressing, and exhausting factors, the potential gradient varied directly with the degree of excitation or depression of the animal, falling to zero at death. The drop in the gradient occurred either abruptly or slowly.

In a series of tissue studies it was noted that the same exciting or depressing factors which caused a rise or fall in the potential gradient also caused destructive changes in the cells of the brain, the liver, and the adrenal cortex, but in the cells of no other organs or tissues of the body. These cellular changes were not seen when death was caused by sudden depression, but only after prolonged depression of the organism.

Electric conductivity, capacity, potential gradients, and temperature of the brain, the liver, and the adrenal cortex of animals under stimulation and depression also paralleled the excitation and depression of the organism as a whole, and corresponded with the histologic findings.

It is therefore suggested that the potential gradient, measured in millivolts, between the brain and other organs and tissues accurately indicates the degree of shock in the animal body.

It is also concluded that in the depression or failure of organs essential to life, a phenomenon takes place in the body that resembles polarization in a Volta liquid battery. If before death occurs the tissue cells are permitted to rest, depolarization (sleep) takes place, and the body recovers. These conceptions are in harmony with modern methods of prevention and treatment of shock.

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