THE SYNDROME OF TRAUMATIC SHOCK.

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In the middle phase of the World War 1914—1918 the Medical Research Committee instituted co-ordinated research in the problem of Shock. An Investigation Committee composed of surgeons and physiologists was formed to receive information from the armies in the field and laboratories at home, to co-ordinate the facts and to circulate resulting conclusions regarding the problem. Opportunities were furnished by the plague of war for the clinical study of this syndrome and observations on men wounded in battle were correlated and compared with experimental findings. A survey of these reports and of contemporary and subsequent work on the problem has been made and the object of this paper is to indicate important features concerning the etiological factors and to state the salient aspects of the treatment of this condition.

The vicious circle of shock.

Physiological Features.

In perusing the literature the writer has been impressed with one dominating consideration namely the blood volume and the circulatory mechanism. There are three emerging factors governing the presence of traumatic shock—

- (a) Decrease in blood volume.
- (b) Decrease in blood velocity.
- (c) Hæmoconcentration.

Under normal conditions only a small portion of the blood capillary bed is utilised by the circulatory mechanism. Attention was drawn by Keogh to the enormous potential capacity of the capillary bed. For example the capacity of the capillaries of skeletal muscle is equivalent to the total blood volume. In addition there are capillary systems of equal magnitude in the lungs and gastro-intestinal

canal. The tonus and contractility of the capillary wall are independent of nerve control but are influenced by metabolites. Lewis has demonstrated the effects of certain substances liberated from injured tissues on the capillary wall and noted the similarity of the effects of histamine. These substances produce dilatation and increased permeability of the capillaries with resulting capillary stasis and oedema of tissues. If a large capillary area were involved in processes of dilatation, congestion and stasis, this would lead to a marked decrease in the available blood volume.

During recent years the view has been propounded that the condition of Shock is due to a circulatory deficiency caused through a loss of blood from the circulation though not from the body. This view was put forward by Malcolm and Henderson who believed that the blood was lost in the venous system. This loss of blood from normal currency may be designated by the Hippocratic term—*exæmia*.

The changes in the blood present in Shock have been investigated by Cannon, Fraser and Hooper by means of enumeration of red corpuscles, hæmatocrit readings and hæmoglobin determinations. These observers found that in cases of shock seen at casualty clearing stations, the red corpuscular count of capillary blood is higher than that of venous blood. The greater the degree of shock which is present the greater the discrepancy in the figures. Similar observations were noted by hæmatocrit and hæmoglobin determinations. Progressive capillary hæmoconcentration is seen with a progressive state of shock. These phenomena have been attributed to blood stagnation in capillary areas associated with a transudation of plasma into tissue spaces. Keith confirmed these observations and found that the plasma volume was reduced by 50 per cent. in cases of severe shock. He also found that when the total available blood volume was below 85 per cent. of normal the condition of the patient was grave; when it was below 65 per cent. the condition was critical and that all patients with shock showed a diminution in total blood volume.

Observations have also been made on the permeability of the capillary wall. Keith found that after a blood transfusion of 900 c.c. in a patient suffering from shock the blood volume had only increased by 150 c.c. ninety minutes after the transfusion; thus in the space of ninety minutes 750 c.c. of fluid had left the circulation. The fate of the patient depends upon his ability to retain fluid in currency which is offered by the tissue spaces or by an external source. If the permeability of the wall of the capillaries is increased to such an extent that the capillaries are unable to retain fluid, then the fate of the patient is inevitably sealed.

The specific gravity of the blood and tissues in experimental shock has been investigated by Vale. It was found in animals that the specific gravity of the blood increased and that of the tissues decreased, denoting inspissation of the blood and an increased fluid content of the tissue spaces. When the condition of shock subsided the specific gravity readings approximated to the normal. Exact measurements have been made by Harkins and Roome of the amounts of fluid lost in the tissues. As much as 1,500 c.c. of blood and plasma has been lost into the injured tissues in cases of severe trauma. In less severe injuries such as a crush injury of the hand or forearm an amount of 600 c.c. of fluid was lost. It is therefore of importance to be aware of this considerable, concealed and constant exudation of blood and plasma. The contention has been put forward by Blalock that shock is due to loss of blood and fluid at the site of the trauma. The majority of authorities are in agreement that the condition of shock is associated with a diminution in circulatory blood volume and a retardation of blood velocity. Further, the heart is competent to

maintain the blood pressure at a satisfactory level if sufficient fluid is available in the circulatory currency and the vaso-motor mechanism is efficient and the peripheral arteries are contracted maximally.

There are other physiological disturbances which usually accompany shock but they are also manifest in other conditions so that they are not considered in this place.

Theories concerning the Causation of Traumatic Shock.

A study of the literature reveals the conflict which has been aroused in the minds of investigators concerning the etiology of shock resulting from trauma. No attempt will be made to critically review the mass of experimental data which has been furnished by so many workers. Neither will a definite pronouncement be made concerning the causative factor or factors, as it may well be that multiple forces are at work. Attention is drawn to the following three hypotheses.

1. The absorption of toxin from the area of trauma.

In 1926 production of histamine from fresh animal tissues was established by Best and Dale, and certain experiments of Cannon supported the view that this or some similar substance was absorbed from the area of trauma in cases of traumatic shock. Dale, Laidlaw and Richards have on the other hand, contrasted the circulatory disturbances of histamine poisoning with those of traumatic shock. O'Shaughnessy and Slome, after careful experimental work, stated dogmatically that the toxic theory of shock has been disproven.

2. The loss of fluid into the area of trauma.

Attention has been drawn to the loss of fluid which occurs into the traumatised area in cases of traumatic shock. Experiments on this relationship were carried out by Blalock, Parsons and Phemister. Blalock further found that he could produce the phenomena of shock in animals by removing a corresponding amount of blood from an artery even in the absence of trauma. The experimental evidence shows the importance of this hypothesis in the etiology of traumatic shock.

3. The reception of nervous impulses from the area of trauma.

Experiments have been performed regarding the association of the central nervous system and traumatic shock. Such experiments were: (a) Section of peripheral nerves to a line; (b) section of the spinal cord; (c) destruction of the spinal cord; (d) induction of spinal anæsthesia. O'Shaughnessy and Slome found as the result of such experiments that when an attempt was made to exclude the nervous impulses from the area of trauma the shock syndrome was less marked.

The Relationship between type of wound and Traumatic Shock.

For the purposes of considering the inter-relationship of wounds and traumatic shock, wounds may be classified as follows according to Cowell—

1. Trivial wounds with slight tissue damage.
2. Moderately severe wounds with disablement of the patient but without immediate danger to life.
3. Serious wounds which will prove mortal unless immediate surgical treatment is instituted.

In the first type of wound traumatic shock is not a feature. In the second type of wound traumatic shock does not occur until some time has elapsed since the wound was sustained. Illustrations of this type of case are fractures, which may be compound, of the long bones and especially the femur; small perforating wounds of the abdomen; injury to the hand or foot, which may be severed from the limbs, and bullet wounds of the soft parts. In the third type of wound marked traumatic shock manifests itself at once. The severity of the shock is in direct proportion to the gravity of the wound. Examples of this variety of wound are—severe perforating wounds of the abdomen; injury of the spine; multiple fractures and extensive damage of soft tissues. Traumatic shock is a marked feature of wounds which involve the abdominal viscera. Factors which favour absorption from damaged tissues favour the development of traumatic shock. Therefore if a damaged area of tissues communicates with the surface only by means of a small opening shock develops very readily. Conversely, when a large area of skin and subcutaneous tissues has been carried away shock is unlikely to develop, or will be mild in character.

The Time Factor in the Development of Shock.

Experience of the treatment of wounds during the Great War showed that the time factor between the inception of the wound and its surgical treatment was important in the development of shock. It was found that in a large series of similar wounds the mortality was 11 per cent. when the patients were treated surgically within three hours of being wounded. When operation was delayed from three to six hours the mortality rose to 37 per cent. If a delay of from six to nine hours the mortality became 75 per cent.

Predisposing Factors in the Development of Shock.

In addition to the type of wound and the time interval between the inception of the wound and treatment there are other predisposing factors in the development of shock. Shock is more liable to occur in a patient who was exposed to cold and suffering from fatigue or hunger at the time of wounding. The rough transportation on a stretcher of a wounded man is liable to precipitate shock. The onset of shock will be accelerated if there is faulty immobilisation of the wounded part due to poor splintage. It was found that the removal of a tourniquet applied for controlling hæmorrhage from a damaged limb was often followed by the development of shock. It is therefore advisable in the case of badly mangled limbs which are to be amputated to leave the tourniquet in position until the operation is performed.

TREATMENT.

In the case of patients with injuries it is important in the first instance to estimate the exact type and degree of the injury so that the possibility of shock developing may be assessed and suitable treatment instituted at once. The objective must be to limit the degree of shock which may develop and to break at the earliest possible moment the vicious cycle of changes which may be initiated by shock. The changes in the body brought about by this vicious cycle may at any time become irreversible and proceed to final dissolution.

ELECTIVE PROCEDURES.

1. The administration of heat.

A patient suffering from traumatic shock is cold and has a clammy skin and therefore heat must be administered and heat loss must be prevented. He must be put to bed in a warm atmosphere and wrapped in blankets and covered with an electric blanket. Other methods may be employed such as hot water bottles, but care must be taken not to burn the patient and a uniform administration of heat is preferable.

2. The administration of drugs.

Patients suffering from injury experience pain and anxiety and the latter psychological state is important and must be relieved. In the absence of injury to the head the best drug for the patient is morphia which, nevertheless, must be given in moderate doses— $\frac{1}{8}$ gr. to $\frac{1}{4}$ gr. If large doses are administered there may result depression of the respiratory centre in the medulla and consequent respiratory embarrassment. In cases of head injury drugs such as potassium bromide may be given by the rectum or sodium phenobarbital can be given intramuscularly in doses of $1\frac{1}{2}$ gr. to 3 gr.

3. The administration of fluid.

In cases of traumatic shock it is essential to increase the circulatory fluid which is in currency. If the circulating fluid in currency is diminished there will be a fall in the blood pressure. If the systolic blood pressure falls to 70 mm. Hg., there is deficient oxygenation of the vital centres in the medulla and if this persists for several hours the vital centres will cease to function.

a. *Blood transfusion.*

The best method of increasing the blood volume is by the administration of whole blood after careful typing and cross agglutination tests. Circumstances will dictate the amount which must be given in each case. It must be remembered that the response of patients with shock to blood transfusion varies considerably and some show very little improvement afterwards.

It is advisable to defer blood transfusion in patients suffering from internal hæmorrhage until operation is undertaken. Patients with penetrating wounds of the chest and abdomen may be dealt with in this way and the blood transfusion commenced during the operation. The amount of blood required depends upon the condition of the patient, but it may be stated that the patient in moderate shock should be given from 500 c.c. to 750 c.c. of blood. If the patient has also been depleted of blood by hæmorrhage he will require a commensurate amount of blood by transfusion. Such patients should receive a large transfusion up to 1,000 c.c. blood and this may have to be repeated. Patients in this category respond much better to large transfusions than to smaller ones. The response of the patient to blood transfusion is estimated by the general condition, the blood pressure and the pulse rate.

b. *Intravenous Lyophile Serum.*

In cases of shock it has been shown by several workers that the blood plasma is most seriously reduced and the escape of plasma proteins is of fundamental importance. The clinical treatment of patients has been directed in general to the restoration of the normal blood volume and especially of the plasma proteins. Experimental evidence supports the use of plasma in the treatment of shock. In these cases the blood protein is restored without an increase occurring in the viscosity of the blood which would be occasioned by the administration of whole

blood. Lyophile serum is readily available, it can be preserved for long periods of time and is almost instantly soluble in distilled water. Since lyophile serum retains its agglutinins, reactions may occur in the patient after administration unless careful typing has been carried out. In cases of shock in which there is marked hæmoconcentration it appears advisable to administer lyophile serum rather than whole blood.

c. *Intravenous Infusion of other Fluids.*

Bayliss carried out an extensive experimental study on fluid substitutes for blood in cases of hæmorrhage and shock. He showed that the fluids commonly employed for intravenous injection in conditions of low blood pressure only produce a temporary rise in blood pressure and the later results are worse than before the infusion was carried out. Beard and Blalock after experimental investigations have pointed out that on leaving the blood vessels protein is carried out along with the fluid, thus further decreasing the plasma concentration and volume. Bayliss recommended the use of a six per cent. solution of gum acacia in cases of shock. Severe and fatal reactions have been reported by Studdiford, who states that while serious reaction is far more likely to follow the use of improperly prepared solutions, yet the introduction of properly prepared acacia has been noted to be followed by deleterious changes in the quality and behaviour of the blood. There is evidence that the acacia solution may interfere with the gaseous interchanges in the red blood corpuscles and this may lead to severe or fatal anoxæmia. It is of interest to note that a large proportion of the acacia is deposited in the liver of experimental animals, causing abnormalities in protein and carbohydrate metabolism.

In cases of shock with resulting injury to the walls of many blood capillaries the use of isotonic saline and glucose intravenously must be guarded. These solutions raise the blood pressure for a very short time and pass out of circulation through the capillary walls carrying with them blood protein. The same statements apply to the use of hypertonic saline solutions. After the administration of an adequate amount of whole blood or lyophile serum a solution of glucose-saline may be employed as an adjunct to maintain the blood volume at a satisfactory level, the initial dangers of shock having been overcome.

4. *The choice of anæsthesia.*

The choice of anæsthetics for operations on patients suffering from shock is limited. The subject has been discussed by Marshall and reference is made to his paper. The first choice is local and regional anæsthesia, but the uses of this form is limited. The second choice of anæsthetic is gas and oxygen and in abdominal cases this may be combined with field block anæsthesia to promote muscle relaxation. With regard to spinal anæsthesia Marshall states that it is important to recognize the type of case which will tolerate this form of anæsthesia. He found that if a recently wounded man had a hæmoglobin percentage of over 100 intrathecal stavain was safe. If the reading was below 100 the blood pressure will certainly fall with the development of further signs of collapse. In patients with wounds less than forty hours old and who have lost blood, spinal anæsthesia is dangerous. In patients with wounds of the abdomen Marshall found that anæsthesia with warm ether vapour had striking advantages owing to quiet induction easy breathing and diminished heat loss. During anæsthesia by ether vapour the blood pressure shows a tendency to rise. Care should be taken by the surgeon not to expose the abdominal viscera a fraction more than is absolutely necessary as this produces a marked fall in blood pressure in the patient who is anæsthetised.

5. The inhalation of oxygen.

The administration of oxygen to the patient suffering from shock has not been used on a large scale and the importance of this therapeutic measure appears to have been overlooked. The oxygen tension in arterial blood is normal in these patients but that of the veins is decreased markedly and there is tissue anoxia. There are important indications therefore for oxygen therapy at least until the blood volume of the patient is restored and the dangers of the critical period of tissue anoxia averted. Oxygen must be administered by means of a nasal catheter, face mask or an oxygen tent.

CONCLUSION.

The syndrome of traumatic shock is reviewed. Attention is called to certain patho-physiological aspects of the condition. The relationship between wound types and traumatic shock is described. Salient features in the treatment of the syndrome are discussed.

REFERENCES.

- BOND, D. B. and WRIGHT, D. G. Treatment of Hæmorrhage and Traumatic Shock by the Intravenous use of Lyophile Serum. *Ann. Surg.* 1938. **107**, 500.
- BLALOCK, A. Acute circulatory failure as exemplified by shock and hæmorrhage. *Surg. Gynæc. & Obst.* 1934. **58**, 551.
- idem* et Cressman R. D. Experimental traumatic shock. *Surg. Gynæc. & Obst.* 1939. **68**, 278.
- BEARD, J. W. and BLALOCK, A. Intravenous injections. *J. Clin. Investigations.* 1932. **11**, 249.
- BOND, D. B. and WRIGHT, D. G. Treatment of hæmorrhage and traumatic shock by the intravenous use of Lyophile serum. *Ann. Surg.* 1938. **107**, 500.
- FREIDLANDER, S. O. & LENHART, C. H. Traumatic Shock. *Arch. Surg.* 1932. **25**, 693.
- HALL, W. K. Effects of intravenous injections of acacia upon certain functions of the liver. *Am. J. Physiol.* 1938. **88**, 123.
- MCDOWALL, R. J. S. Experimental Shock. *Brit. Med. Jour.* 1933. **1**, 690.
- MAHONEY, E. B. A study of experimental and clinical shock with special reference to its treatment by the intravenous injection of preserved plasma. *Ann. Surg.* 1938. **108**, 178.
- MARSHALL, G. Anaesthetics at a Casualty Clearing Station. *Proc. Roy. Soc. Med.* 1917. **10**, 27.
- MOON, V. H. Shock, Its Mechanism and Pathology. *Arch. Path.* 1937. **24**, 642, 794.
- O'SHAUGHNESSY, L. and SLOME, D. Etiology of traumatic shock. *Brit. J. Surg.* 1935. **22**, 589.
- STUDDIFORD, W. E. Severe and fatal reactions following the intravenous use of gum acacia glucose infusions. *Surg. Gynæc. & Obst.* 1937. **64**, 772.
- Numerous Authors. Reports of the Special Investigation Committee on Surgical Shock and Allied Conditions. *Med. Res. Council Special Reps:* Nos. 26 & 27.

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