SOME ASPECTS OF WOUND SHOCK WITH EXPERIENCES IN TREATMENT.

By Captain W. d'A. Maycock, M.D., McGill,
Royal Army Medical Corps,
AND
Colonel L. E. H. Whitby, C.V.O., M.C., M.D.Camb., F.R.C.P.
(Army Blood Transfusion Service).

The proper treatment of any bodily disorder is necessarily based upon an understanding of the fundamental changes responsible. From the clinical aspect the diagnosis of the disorder is made by correlating signs and symptoms. Many of these signs may be common to different pathological conditions and it is only when one or more are pathognomonic that a diagnosis can be made by rule of thumb. Most other states demand judgment and experience whilst some require elaborate supplementary scientific investigations. There can be no better example of these generalizations than the variety of conditions which give rise to the signs and symptoms found in what is conveniently called "shock." Shock is a broad term which describes that state in a person exhibiting lowered vitality and circulatory disturbances following upon mental or bodily injury, including the deliberate procedures of a surgical operation. The state may range from a mere faint, which quickly passes, to gross circulatory failure which cannot be recovered from. The classical symptoms and signs are a lowered blood-pressure, a pulse which is usually fast and of poor volume, pallor and/or cyanosis, especially of the lips and nails, sweating and coldness. In cases of injury the mental state is often surprisingly clear and alert, whilst
Some Aspects of Wound Shock with Experiences in Treatment

Pain may be very little in proportion to the amount of tissue damage. Vomiting is common. When the blood-pressure is persistently low, later signs include reduction in urinary output followed by anuria. This battery of symptoms, sometimes trivial, sometimes serious, obviously needs to be carefully analysed in relation to cause, if proper treatment is to be prescribed. Too often the condition of "shock" is accepted as a single clinical entity and the treatment given is as vague and unscientific as the diagnosis.

War has brought the whole subject of shock very much to the fore and there has been much experience to assess and expand the valuable observations made in the war of 1914–1918. There has been opportunity to study the reactions of the human body to various combinations of injury, fear, exposure, haemorrhage, burns, crushing, multiple fractures, head wounds and other features such as delay between injury and treatment. These observations, made on an unrestricted age group, for casualties now include the very old and the very young and not simply the fit young Service man, need to be carefully classified into groups in order that the clinician may be presented with descriptions sufficiently clear to enable him to visualize the fundamental cause of the symptoms in each individual case. New causes of circulatory collapse in the injured as well as factors which may modify the clinical picture will doubtless be discovered when the experimental and clinical work of the war is analysed and correlated. In the meanwhile the following description gives some of the known causes of circulatory collapse in the injured. The voluminous literature of the subject is briefly reviewed later.

Causes of Circulatory Collapse in the Injured.

(A) Blood-Volume Reduction.

This is undoubtedly the commonest cause of circulatory collapse following upon injury and is the group in which transfusion of the appropriate fluid is usually effective. For this reason transfusion may be regarded as the most important single measure for resuscitation work. Reduction in blood-volume causes circulatory embarrassment because cardiac filling is imperfect. Consequently cardiac output, as well as the efficiency of the driving force, are greatly reduced. This leads to imperfect nutrition, particularly of the peripheral parts, and is a progressive state in which metabolism falls to a low ebb and vital tissues finally become damaged beyond recovery. Thus, in the later phases of blood-volume reduction, the peripheral capillaries may become permeable so that plasma leaks from the circulation into the tissue spaces.

Blood-volume reduction may arise in a number of ways; the immediate or the final effects differ according to the manner in which the reduction is brought about.

(1) Haemorrhage.—Frank haemorrhage means a loss of all elements of the blood. In healthy people an acute loss not exceeding a pint is immaterial.
but a loss of two pints or more is a geometrically progressive embarrassment to the circulation. Nevertheless it has been found that life can still continue for a few hours even when as much as six or seven pints are lost. And provided that adequate replacement can be made without delay many lives can be saved. The physiological reactions following upon haemorrhage are firstly a compensatory vasoconstriction in an effort to maintain a reasonable blood-pressure and to make the best use of what blood remains, and, secondly, the absorption of fluid from the tissues in an attempt to restore blood-volume. This restoration is a more vital and urgent requirement than the making up of lost haemoglobin. The symptoms of shock disappear in those who survive the haemorrhage sufficiently long for blood-volume to be efficiently restored. The same occurs in those whose blood-volume is restored by transfusion. But those whose blood-volume remains reduced and whose circulation therefore continues to operate in an embarrassed manner progress to the stage of irreversible capillary damage and they begin once again to lose circulatory fluid (plasma), this time into the tissue spaces. In these, the blood becomes concentrated and this increased viscosity adds to the difficulties of the heart. Such states arise under the conditions of delayed evacuation found in battle rather than in air raid casualties who usually reach hospital within a short time of wounding.

(2) Plasma Loss.—(a) At Site of Injury.—Whenever there is tissue injury there is an exudation into the injured area. This can be observed in an injured limb when a tourniquet is removed and is shown by a rapid swelling of the tissues in the injured area quite apart from haemorrhage itself. And so the blood lost in an acute haemorrhage may not represent the whole of the fluid lost to the circulation; long after the haemorrhage has ceased plasma exudation into the wounded area may continue. Plasma exudation is a serious aspect of blood-volume reduction because of the increase in blood viscosity.

(b) Crush Injuries.—Considerable plasma loss from the circulation occurs when any part of the body is compressed or crushed for long periods. This happens even though there is no rupture of blood-vessels or severe tissue-damage such as a fracture. The exact mechanism of this phenomenon, which is a progressive oedema into the crushed tissues accompanied by the formation of skin blisters, is not completely understood. The plasma loss may be great enough to cause a vast reduction of blood-volume. The early phases may therefore be associated with a falling blood-pressure and other symptoms of shock though, in the late phases and sometimes in the early ones, there may be a rising blood-pressure which may possibly be a symptom of developing or established renal incompetence.

(c) Burns.—There is always an exudation of plasma into a burned area and this lesion provides the purest example of blood-volume reduction due entirely to plasma loss. The amount lost may be very large and so cause a gross increase in blood-viscosity from haemoconcentration. There appear
also to be other factors, tentatively suggested to be toxic substances derived
from the destroyed tissue, which contribute greatly to the symptoms of
circulatory collapse and which may not come into operation until a day or
two after receiving the burn.

(d) Gross Dehydration.—Body water is maintained at a constant level
by a balance between fluid intake and output. Should intake cease, output
nevertheless continues. The process in a person dying of thirst is that he
first excretes tissue fluid and when this source is exhausted he begins to lose
fluid even from the circulation itself. The last stages of dehydration therefore
give rise to blood-volume reduction accompanied by haemoconcentration
which produces symptoms of circulatory collapse. It will be appreciated
that under battle conditions severe grades of dehydration may occur. Men
are often potentially dehydrated before they are even wounded. They may
be in places where water is difficult to obtain whilst exertion and sweating
increase the fluid loss. When wounded, the reaction to blood loss is to
absorb tissue fluid into the circulation. And if no fluid by mouth is available
advanced degrees of dehydration may occur, becoming more and more
pronounced the longer the delay between wounding and receiving treatment.
It is for this reason that the giving of fluid by mouth is such an important
part of the treatment of battle casualties. Not only does such fluid over­
come dehydration but also helps the patient to restore his own blood­
volume efficiently and quickly.

(B) Psychogenic and Neurogenic.

Emotion, fear and pain are known to influence cardiac action and to
produce fainting or syncope, brief or prolonged. The patient may exhibit
alarming signs of cardiac embarrassment including a low blood-pressure and
the peripheral signs of sweating, pallor, cyanosis and coldness. This may
occur with or without definite bodily injury. The state, in its pure form,
usually responds to conservative measures which include relief of pain,
reassurance, warming up and the administration of hot stimulating drinks;
when it occurs in combination with definite injury the amount of collapse
due to nervous influence cannot be assessed in advance; it is only revealed
when conservative treatment alone produces an obvious improvement in
condition. No casualty, in whom the nature of the wounds is such that
he obviously falls into the first category (blood-volume reduction), should be
treated for prolonged periods with conservative measures only in the hope
of achieving a result. It is therefore important to examine all patients
thoroughly in order to be aware of the nature and extent of the injuries
before attributing their symptoms to neurogenic causes alone.

(C) Toxaemia.

During the war 1914–1918, it was found that casualties admitted with
an established gas gangrene infection often exhibited circulatory embarrass­
The removal of an infected limb would sometimes cause such symptoms to disappear. This again is a feature more commonly found in battle casualties than in those quickly evacuated from an air raid. The surgical treatment of infected cases should not therefore be delayed longer than possible.

(D) Fat Embolism.

This phenomenon which has been rediscovered as the result of the many bony injuries of total war is associated with general collapse, apathetic, delirious or comatose mental state and sweating. Unlike the conditions described above, the blood-pressure is usually well maintained. But unless this important observation is made the clinical state is not readily differentiated from that of other causes of collapse. The importance of bearing fat embolism in mind is that it is usually made worse by transfusion.

Factors which may contribute to Circulatory Collapse in the Injured.

It may be accepted that blood-volume reduction, whether from blood loss or plasma loss or both, is by far the commonest cause of progressive circulatory embarrassment in the injured.

Nevertheless there are a number of factors, briefly summarized below, which are known to have or thought to have a bearing on the problem of shock. Some of these operate as part of the vicious circle of progressive circulatory collapse whereas others are believed to come into play in special types of injury.

Anoxia.—One of the symptoms of an embarrassed circulation is cyanosis and anoxia may therefore be regarded as part of the vicious circle of events that finally leads to death. Though anoxia does not cause shock, its relief may considerably assist recovery. It is known also that an unskilfully-administered anaesthetic may rapidly cause circulatory collapse. There is no special virtue in gas and oxygen anaesthetic unless it is skilfully given.

Pain.—This factor undoubtedly contributes to circulatory collapse and continuous bombardment of the nervous system by noxious impulses is regarded by some as one of the fundamental factors in producing a state of shock. In practice the prevention of the pain factor is accomplished by the administration of morphia and occasionally by judicious local anaesthesia. A spinal anaesthetic is considered to be dangerous.

Cold.—Continuous exposure to cold has long been recognized as a contributory factor. Hence the importance of facilities for warming patients. At the same time overheating is deleterious and must be avoided.

Adrenal Factors.—Certain experimental results indicate that adrenal cortical-extracts may be useful in the treatment of shock but the evidence is by no means convincing and in the present state of knowledge the administration of these extracts must be regarded as purely experimental.
Some Aspects of Wound Shock with Experiences in Treatment

Reception of Casualties.

Experience on active service and at home has shown the importance of resuscitation work and made it quite clear that the work needs to be carried out as a separate department with its own premises, specially allotted, and highly-trained staff, and with its own equipment as distinct from that of the rest of the hospital. The senior medical officer should be a physician of experience with junior officers adept at transfusion and nurses or orderlies familiar with all the simple apparatus used. All the staff should be thoroughly drilled in procedure including work under adverse conditions of emergency heating or lighting. Apparatus is required for the giving of transfusions, together with an adequate stock of blood, plasma or serum, and saline, as well as stands for the suspension of the transfusion bottles, simple surgical instruments for cutting down and inserting a cannula, facilities for administering oxygen, arresting haemorrhage, making warm drinks, warming blankets, and drugs for the relief of pain and treatment of collapse. There needs to be a plentiful supply of cuffs for a blood-pressure apparatus so that a cuff can be left in position on a patient for several observations without disturbance. If these are provided one recording instrument will serve for many beds.

On reception, all cases, except chest or head injuries, should be placed in the head low position between blankets already warmed and the clothes be removed with scissors. Common sense will dictate whether a case is better left on a stretcher for a time or whether an immediate move into bed is justifiable. In the former case the stretcher should be placed on the bed. Manipulation, movement and disturbance must be reduced to a minimum.

Assessment.

The first requirement is to make a clinical estimate of the state of the patient and to sort out, as far as possible, those who fall into the neurogenic and psychogenic class, with little or no bodily injury, from those who, from the nature of their wounds, have obviously suffered a definite reduction in blood-volume either from blood loss or plasma loss. One has to consider the possibility of complicating factors such as dehydration, toxæmia or fat embolism, and to judge whether anoxia or other symptoms are contributing to the distressed state. Having made these estimations, reasonable treatment can be prescribed. For making this assessment it has been found that the amount of sweating, coldness or pain is not a reliable quantitative guide to the severity of the case, whilst the mental state may be definitely misleading. Those at the point of death may be acutely alert and rational. The pulse-rate too has not always been found to increase in proportion to the severity of the state and, though it may be accepted that the more severe cases have usually a rapid pulse, this feature may be entirely misleading especially if divorced from the blood-pressure reading. The volume of the pulse is more reliable than the rate. Pallor is of importance. It not only suggests blood loss but in rapidly evacuated cases gives some idea of
the amount of compensatory vasoconstriction in response to blood-volume loss, which compensation in some cases, especially the young, may be sufficient to maintain a reasonable blood-pressure.

The blood-pressure itself, not so much a single reading as serial ones at ten to fifteen minute intervals, may be regarded as the one really reliable measurable clinical observation for making a reasonable quantitative assessment. A low blood-pressure or a blood-pressure which continues to fall despite conservative treatment is always a serious sign. A relatively high blood-pressure is not always a favourable one; the observation needs to be correlated with the nature and extent of the injuries. If the blood-pressure appears to be unexpectedly high, in relation to the probable amount of blood lost, some of the optimistic reading needs to be discounted. Unexpectedly high blood-pressure may be found in hypertensive subjects and in young subjects still in the stage of reasonably efficient compensatory vasoconstriction. If neglected or treated merely with conservative measures sudden collapse is usual.

It is therefore very essential to have full knowledge of the nature and extent of the injuries in order that these may be correlated with the other clinical observations and enter into the complete estimate. This knowledge must be obtained with the minimum of disturbance and manipulation. One of the most important items of equipment is a large pair of carpet-fitter's scissors with which clothes can be ruthlessly and completely removed without disturbance.

TREATMENT.

Relief of pain with morphia, warming with hot blankets and bottles or cradles, administration of fluid by mouth, preferably warm drinks such as hot coffee, all of which can with advantage contain a pinch of salt, should be a routine, with the exception of abdominal wounds from whom fluids should be withheld.

Sympathy and encouragement to all patients is important. All who are judged to have suffered significant blood-volume reduction, whether this be shown by low blood-pressure or by common-sense deduction from the nature of the wounds, should be transfused without delay. Transfusion raises such questions as choice of fluid, amount to be transfused and the rate at which it is to be given.

Choice of Fluid for Transfusions.—On first principles those who have lost blood require blood, those who have lost plasma require plasma and those who are dehydrated require saline. But treatment is greatly influenced by the supplies available. Blood, being a perishable fluid, is not always ready in large amount at the right time and in the right place, whereas stocks of durable protein-containing transfusion fluids—plasma or serum in fluid or dried form—can be accumulated anywhere without waste. Furthermore the primary object of the transfusion is to restore blood-volume with a fluid which will remain in the circulation and this is far more
Some Aspects of Wound Shock with Experiences in Treatment

vital than the restoration of the lost oxygen carrying power. Plasma or serum is therefore suitable, in the absence of blood, for the restoration of blood-volume due to frank haemorrhage, but it is an advantage, when the transfusion needs to be large, if blood is available, for at least one pint in three to be blood, so that some part of the oxygen carrying power can be restored. On the other hand when blood-volume reduction is due to plasma loss it is physiological to replace with plasma, whereas blood, in that the corpuscular content adds to the viscosity of the circulating fluid, is contra-indicated. Saline or glucose being non-protein fluids, are not suitable for blood-volume restoration in that the effect lasts only for the short time which the fluid is retained in the circulation. Furthermore if given in large amount they produce pulmonary oedema. Administration of saline or glucose-saline should be restricted entirely to those judged to be suffering from dehydration, as shown by dry mouth, scanty urine, desiccated appearance, long delay between wounding and reception. In these the effect of saline is remarkably beneficial. Every pint of saline should be alternated or mixed with a pint of 5 per cent glucose.

Amount to Transfuse.—The object of the transfusion is to make an approximately quantitative replacement of the protein fluid lost and the amount should theoretically be controlled by a blood-volume determination. Cases which have been especially investigated from this scientific aspect (Kekwick, Maycock, Marriott and Whitby, 1941) have shown that a reasonable clinical guide to the sufficiency of a transfusion is the effect on the blood-pressure and that a rise of 10 to 20 mm. Hg can be anticipated for every pint transfused. When the anticipated rise does not occur continued or renewed bleeding should be suspected. It can therefore be estimated that a casualty with an initial blood-pressure of 50 mm. Hg will probably require three or four pints to restore the blood-pressure to a point sufficiently high to enable him to withstand operation. It may be assumed also that any wounded person whose blood-pressure is persistently below 100 mm. Hg will never be harmed by the administration of one or two pints.

Rate of Transfusion.—Transfusion in the injured can be practised at a much greater speed than is usual in ordinary medical practice, for it may be assumed that prior to wounding the heart muscle was in a healthy condition and that the rational procedure is to replace the acute blood loss as quickly as possible. The early stages of a transfusion may therefore be conducted at the rate of a pint in ten minutes until the blood-pressure is in the region of 90 to 100 mm. Hg, when the rate should be halved or quartered and afterwards adjusted according to progress. In some patients, however, a fast rate is not well tolerated and this may be shown by the occurrence of rigors. In such cases a slowing of the rate is almost instantly effective.

Maintenance of Condition.—Resuscitation does not necessarily end in the ward. A patient may deteriorate rapidly as the result of delay or in the operating theatre itself because of the movement on to the table, the anaesthetic, further loss of blood or the surgical procedure itself. It is as well
therefore for the last bottle set up in the ward to be administered at slow
drip rate so that this accompanies the patient to the theatre and be speeded
up should there be any falling off in the general condition.

**Oxygen Administration.**—Cyanosed patients are made more comfortable
by the administration of oxygen which is especially useful in cases of chest
wounds. The administration needs to be in high concentration and for
practical purposes the B.L.B. mask is the only really efficient apparatus.
Oxygen should be regarded as an adjunct for use in selected cases.

**Experiment Aspect.**

The foregoing straightforward opinions and recommendations are based
on a vast amount of experimental work and a more limited number of clinical
observations on the human subject. The following is a very brief critical
review of some of the more important work.

**Blood-Volume Reduction.**—Keith (1919) during his studies on the wounded
in the last war conclusively demonstrated that diminution of the circulating
blood volume was the cardinal pathological change in those exhibiting the
symptoms of shock; his observations have been confirmed experimentally
by many workers.

Gasser, Erlanger and Meek (1919) state that the blood-volume is dimin­
ished in animals, no matter what method is used to produce shock.

The most obvious cause of a lowered blood-volume is *haemorrhage*, either
external or internal. But a diminished blood-volume is found also in cases
of severe shock in which blood loss has not been large enough to explain the
state of the patient. Hæmorrhagic shock and shock without great loss of
blood are in many ways similar and the effect of even slight hemorrhage in
increasing the state of shock emphasizes the relationship between the
reduction of blood-volume by haemorrhage alone and reduction by some
other condition (Roome, Keith and Phemister, 1933). Shock and haemor­
rhage have been differentiated by the observations that in the former
haemoconcentration is a feature and in the latter dilution occurs (Moon and
Kennedy, 1932). It has also been argued that in shock there is congestion of
the visceral blood-vessels, accompanied by oedema and petechial hæmor­
rhages, while in hæmorrhage autopsy reveals an anæmic condition of the
tissues. This broad distinction between hæmorrhagic and traumatic shock
is probably unjustified for, experimentally, Parsons and Phemister (1930)
produced traumatic shock in dogs in which haemoconcentration was rarely
observed and Blalock (1934) showed that maintenance of a low-blood­
pressure for several hours by continued small hæmorrhages caused changes
in the tissues resembling those described above as following shock. More
recently Dunphy, Gibson and Keeley (1941) have stated that the post­
mortem microscopical changes in animals succumbing within a few hours
from thermal and mechanical trauma showed no evidence of capillary
damage and closely resembled the changes following acute hæmorrhage;
after a longer period (six to twelve hours), however, there was histological evidence of capillary damage and loss of fluid into the viscera. The available evidence suggests that the early morphological findings in shock and haemorrhage are in some respects similar and that later in both conditions there is damage to the small blood-vessels.

Loss of red blood cells is less important than the diminution of blood-volume in causing the harmful effects of haemorrhage for Peyton Rous and Wilson (1918) showed that rabbits could be deprived of 75 to 80 per cent of their circulating haemoglobin without suffering great harm provided the blood-volume was maintained.

To explain the observed diminution of blood-volume in cases of shock, in which haemorrhage has not been great, is difficult. With few exceptions these cases have all suffered severe injury involving the destruction of relatively large amounts of tissue.

Traumatic Toxaemia.—The general impression given by the work of the M.R.C. Special Shock Committee during the last war was that gross tissue injury, especially of muscle, was attended by the formation, in the damaged tissue, of a toxin or toxins which was washed into the general circulation and caused circulatory collapse. The experimental work of Dale, Laidlaw and Richards on histamine, briefly described in Special Report Series No. 26, 1919, lent strong support to this conception, for injections of sufficient histamine into a cat were shown to cause an arteriolar constriction, loss of tone and abnormal permeability of the capillaries, haemoconcentration, a diminution in blood-volume and finally death. The blood had passed out of currency and stagnated in the dilated capillary bed; in addition plasma was lost through the capillary walls. It was stressed that histamine poisoning in an anaesthetized animal and shock in a wounded man resembled one another and that this similarity suggested that the phenomena of shock might be due to toxic substances formed in injured tissue. The identity of the two conditions was never claimed.

The experiments of Cannon and Bayliss (Special Reports Series No. 26, 1919) led them to conclude that the collapse of the circulation was caused by poisonous substances formed in the injured tissue. Later workers have failed to demonstrate satisfactorily the presence of any toxic substances. Among them, Dragstedt and Mead (1937) state that they failed to find any vasodepressor toxin in the blood and lymph of dogs during experimental shock. Rose and Browne (1940) pointed out that in patients with shock, the total blood histamine was lower in the severer cases, and suggested that this decrease might be due to fixation of the substance in the gastrointestinal tract or injured tissue. Although there is no evidence satisfactorily demonstrating the presence of toxic substances it cannot be denied that they may play some part in shock.

Fluid Loss at the Site of Injury.—About 1930 much work began to appear in America which tended to show that it was unnecessary to assume that a toxic substance was formed in injured tissue and that much of the experi-
mental work adduced in favour of traumatic toxæmia could not be repeated successfully.

Cannon and Bayliss had shown that if the blood supply to a traumatized limb were occluded, the blood-pressure did not fall and shock did not develop. If the circulation were restored the blood-pressure started at once to decline and shock developed. The same investigators removed the injured limb and compared its weight with that of its intact fellow and concluded that the increase in weight of the injured limb (which was due to extravasated blood and plasma) was insufficient to account for the death of the animal. Cannon and Bayliss also showed that preliminary denervation of the injured limb did not prevent the onset of shock.

Blalock (1930) and Parsons and Phemister (1930) produced shock in dogs by traumatizing one hind limb. They found on comparing the weights of the injured and intact extremities that the increase in weight of the injured leg, which was assumed to be due to loss of blood and plasma from the circulation, amounted in most instances to about half the calculated blood-volume. The method of estimation of weight of the limbs employed by Cannon was criticized on the grounds that it took no account of the swelling in the loose inguinal and retroperitoneal tissues, which was usually found when the thigh was injured. Blalock therefore amputated the hind extremities through mid-abdomen, and then bisected the hind quarters by sawing up the spinal column. Parsons and Phemister, however, excised the limbs by severing symmetrically the tissues attached to the innominate bones. In spite of this difference in technique both found that there was sufficient loss of blood and plasma into the injured part to account for the fall in blood-pressure. No evidence of toxic substances in the blood returning from the injured limb was found. Cannon and Bayliss apparently did not attempt to produce shock in animals after occluding only the venous return from the injured leg. Blalock showed that when such a procedure was carried out, shock could still be produced; he observed also that on releasing the venous obstruction the slope of the blood-pressure fall became less steep, instead of more precipitate as one would expect if the blood were carrying poisonous substances into the general circulation. Parsons and Phemister state that if the venous drainage of the injured limb is obstructed the shock develops more rapidly and is of a severer degree than when the veins are patent.

Blalock and Parsons and Phemister attempted to demonstrate the presence of toxins in the blood returning from the limb by introducing it in various ways into normal animals and animals whose condition had been weakened by hæmorrhage. The experiments met with no success.

Blalock and his associates in later papers showed that in mild trauma of the extremities sufficient fluid is lost at the site of the injury to explain the lowered blood-pressure and further that this fluid analytically closely resembles plasma. It was also shown by Johnson and Blalock (1931) that the loss of plasma is more deleterious than the loss of whole blood or red blood cells alone.
That local fluid loss plays an outstandingly important part in causing the development of shock is now generally recognized. That it alone is responsible is probably untrue and other factors must be considered. Some of these formerly occupied the position now held by local fluid loss and were considered the prime cause of shock. Now they are regarded as secondary factors of varying importance.

Nervous Factors.—The nervous exhaustion theory of the origin of shock was the leading theory up to the time of the last war, when it was superseded by the theory of traumatic toxaemia. In 1935 new evidence in favour of this theory was produced by O'Shaughnessy and Slome. They first performed experiments to see if they could demonstrate a toxin and failed. They next investigated the amount of fluid loss occurring at the site of injury and concluded that it was insufficient alone to explain the state of shock and that other factors must be considered. They found that they could produce shock by traumatizing a limb which was connected to the body by the nerves alone and which was nourished by an artificial circulation from a second cat. The injured animal died, but the results of the experiment were complicated by the death of the donor cat. They also showed that the elimination of nervous impulses by (1) nerve section, (2) spinal cord section, and (3) spinal anaesthesia, prevented the development of shock. From their results they concluded that local fluid loss and nociceptive nervous impulses are both important aetiological agents. While not attempting to dogmatize on their relative importance, they personally believed that the nociceptive impulses were of greater importance than the local fluid loss. No attempt was made to explain how the nociceptive impulses caused the circulatory collapse. Attempts were soon made to repeat this work. Bell, Clark and Cuthbertson (1938), Blalock and Cressman (1939) failed to obtain the same results. The latter group of workers found that if they used choralose as the anaesthetic, which was used by O'Shaughnessy and Slome, they could obtain evidence showing that nociceptive impulses were of importance but under no other experimental conditions. Louber, Kabat and Welte (1940), however, satisfied themselves that they could reproduce O'Shaughnessy and Slome's experiments.

Adrenal Medulla.—Porter (1907), Seelig and Lyon (1909) all contended that vasoconstriction was a feature of shock and that a peripheral vasodilatation due to collapse of the vasoconstrictor system through exhaustion did not occur save perhaps terminally. Porter was able to show experimentally that the vasomotor centre was active in shock. Recently the role of the adrenal medulla has been re-emphasized, particularly by Freeman (1935). It is well known that the adrenal medulla is activated by pain, cold, anxiety, all states likely to be present in shock. It has been shown experimentally that the infusion of adrenalin in suitable amounts will cause an oligoëmia, extrusion of plasma, a low blood-pressure and haemorrhages in various tissues. The blood-volume has been shown to decrease by as much as 27 per cent. The explanation of the role of the
adrenal medulla is that the sympatho-adrenal activity tends to ensure the blood supply to the vital centres at the expense of a generalized vasoconstriction, especially in the skin and splanchnic area, which causes eventually stasis of blood in the capillaries, increased permeability of the capillary walls and loss of plasma. Cannon (1934) has also pointed out that overactivity of the sympathetic nervous system and excessive secretion of adrenalin may lead to dilatation of the small vessels in muscles and the consequent passage of fluid into the tissue spaces. Normally in active muscle this fluid would pass into the lymphatics but, in the shocked patient, this pumping action of the muscles is lacking. In contrast to this evidence in favour of the possibility of the adrenal medulla being active in shock, Davis (1937) produced shock by haemorrhage, trauma, and the injection of adrenalin and histamine. He found that the tissue changes produced by adrenalin did not resemble those caused by haemorrhage or trauma and concluded that they lent no support to the theory that the adrenal medulla was active in shock. Similarly Hamlin and Gregerson (1939) were unable to show in unanaesthetized animals that adrenalin caused a diminution in blood-volume.

While there is evidence for both sides, it seems most probable that the adrenal medulla together with the sympathetic nervous system is active in shock. The importance of this activity is difficult to assess. One should probably regard it as an accompaniment of the shocked state.

Adrenal Cortex.—The similarity between shock produced by mechanical trauma and the condition which follows bilateral adrenalectomy is striking. That there may be a relative deficiency in the elaboration of the cortical hormone in shock has been an attractive theory, since lack of this principle causes amongst other things a hypotension with hemoconcentration and increased viscosity, increased pulse rate and an increased sensitiveness to haemorrhage and trauma. Swingle and his collaborators from their work on trauma (of intestines and muscle) in adrenalectomized animals were led to conclude that the capillary atony caused by the lack of cortical hormone increased the permeability of the capillaries and they observed that infusions of saline were ineffective in raising the blood-pressure unless cortical extract was administered simultaneously. They also observed that the cortical hormone itself had a blood-pressure raising effect. Weil and Browne (1940) found that there is an increased excretion of cortin in the urine after surgical operations; this observation may be connected with the earlier findings of Selye (1937) that exposure of animals to various damaging agents is accompanied by a hypertrophy of the adrenal cortex. The changes in the cortex found by Selye occur in a comparatively short time after injury but there do not appear to have been any similar observations in human beings dying of shock. These observations would indicate that one of the body’s reactions to an injurious stimulus is an increased activity of the adrenal cortex, and that the need for the cortical principle is in some way increased. However, the finding of an increased urinary excretion of cortin
in human beings would suggest that excess amounts are being produced or that there is a diminished utilization or destruction.

It is difficult to reconcile these findings and to knit them into a satisfactory exposition of the role of the adrenal gland. Certain experimental results, however, indicate that adrenal cortical principles may be useful in the treatment of shock but the evidence is in no way conclusive.

Heuer and Andrus (1934) produced a fall in blood-pressure by injecting aqueous extracts of the contents of loops of bowel which had been obstructed and they observed that the immediate injection of cortical extract prolonged the life of the animal and tended to prevent the fall in blood-pressure and the loss of plasma from the vessels which occurred in the absence of this treatment. Selye and Dosne (1940) produced shock in rats by injuring the thigh muscles and manipulating the intestines. The survival period of the group injected with corticosterone was significantly longer than that of the untreated group. Desoxycorticosterone and extracts of adrenal cortex were ineffective. Selye, Dosne, Bassett and Walker (1940) found that not only was desoxycorticosterone ineffective but actually harmful in the treatment of their animals. Cortical principles have also been claimed to be helpful in the treatment of burns in which the blood sodium is lowered.

It is not possible at present to assess the usefulness of cortical preparations in the treatment of shock or the part played by the adrenal cortex in producing the state of shock. The present evidence would indicate that such preparations may be found to be useful in selected cases.

This short survey of some of the literature is not intended to be a comprehensive review. Its purpose is to touch upon some of the more important aspects of the experimental work on shock and to give an idea of the many-sided character of the condition without undue emphasis upon any single feature.

REFERENCES.

W. d'A. Maycock and L. E. H. Whitby