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Shock : a review of the literature with special reference to that occurring post-operatively

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Shock--A Review of the Literature with Special Reference to
that Occurring Post-operatively

by
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Shock--A Review of the Literature with Special Reference to
that Occurring Post-Operatively

Shock is a condition which has been recognized since Pare, in 1597, noted death following hemorrhage and injury (31). He noted convulsions following loss of blood, and warned, "Syncope unsuccored often leads to death." He described "another disposition called commotion--which is caused by falling from a high place on something solid and hard, or by blows causing contusions, as stone or mass, or the blow of a lance, or an artillery blow, or thunder falling near a person, or other similar things." The first reference of shock occurring post-operatively was made by Abernethy in 1804, (140) who said the patient "sank in shock in consequence of the operation." In the literature there is no differentiation between post-operative shock, traumatic shock, dehydration collapse, anaphylactic, burn, and toxic shock--the results are essentially the same--the clinically recognized picture, shock. This same final condition is reached through different instigating mechanisms. The process is similar in that all eventually have increased permeability of capillaries and decreased volume of circulating blood, decreased blood pressure, anoxia, and establishment of a vicious cycle.

Much is known about shock but the actual cause is as vague now as when first theorized. It seems that every one who has studied the condition since has advanced a theory as to its cause, none of which has ever been satisfactorily proved. A good deal of

research has been done, however one must not forget that the conditions causing shock experimentally, and the reactions of laboratory animals, may both vary greatly from the conditions and responses found in man. Because of this, the most valuable facts have been gleaned from clinical experience. Here, various attempts at therapy constitute the experimental work. For this reason therapy must necessarily be included in a study of shock.

In the first studies there was no differentiation between the shock occurring during operation, at the time of injury or psychic upset, and that occurring later. In the latter part of the nineteenth century shock was separated into primary and secondary shock. Primary occurring at the time of injury, or when one experiences an unfavorable psychic stimulus, is considered to be the same thing as syncope or fainting and neurogenic in origin. Secondary shock occurs several hours after injury or operation and is quite different from primary. It is this secondary shock to which the term "shock" really applies and to which this paper shall be confined.

There has been a great deal of experimentation and clinical observation done on shock. This paper is an attempt to review the literature and present the more emphasized theories and facts known about it and the modern conception of shock. Due to the large amount of repetition in the literature, a selective bibliography is used. The study of post-operative shock is emphasized.

The History of Shock

In the beginning of the eighteenth century Stephen Hales observed a constriction of the veins with a rise in venous pressure in animals bled to death (140). In experiments on the horse, dog, sheep, and deer, he proved no correlation existed between the amount of blood lost and decline in blood pressure. Thus was initiated the study of a condition yet unsolved although much has been learned about it. In 1743 (140) the word "shock" appears in the translation of LeDran's work into English. In 1770 (140) Woolcomb used the same term. John Hunter employed the word occasionally in his writings in 1840. In 1795 Bell, (140) in his "Discourses on the Nature and Cure of Wounds," wrote about shock. In 1795 James Latta, in his "Practical System of Surgery," often employed the word. The first use of the term as occurring post-operatively was made in 1804 by Abernethy who commented on a patient who "sank in shock in consequence of the operation." In 1818 Hennen said, "autopsies often show no cause of death in shock." In 1824 Cooper (140) said, "Injury destoryes life, when most severe, by shock to the nervous system without reaction...death from shock leaves no pathological criteria." In 1826 Travers (160) said, "Death ensuing upon injuries of parts not essential to life even when unattended by hemorrhage, and upon operations not usually esteemed hazardous is not just due to the patient's idiosyncrasy." He was against blood letting for therapy of shock.

In 1831 O'Shaughnessy (127) said, "The universality of the

diminution of the quantity of water in cholera blood is extensively and satisfactorily confirmed." He also said the saline matter of the blood was deficient.

In 1831 Latta (105) said, "Early injection of intravenous saline prevents stagnation of the blood...relieves the symptoms of dehydration." He also said it relieved "air hunger" due to deficient circulation of blood.

In 1834 Delcasse (140) said that shock produces nervous commotion which leads to death.

In 1839 Davy (140) said that there was a fall in specific gravity of blood in animals "blooded" to death.

In 1858 Lister (31) said that the arterial constriction resulting from a blow in frogs is due to a twofold mechanism; local, and central through the cerebrospinal nerve.

In 1859 Gross (31) said that disturbances of the nervous fluid was the most important factor in shock.

In 1864 Goltz (31) made his historical experiments on frogs. He showed that reflex inhibition of the heart follows a blow on the frog's abdomen and when the heart starts again little blood is expelled for it has accumulated in the abdominal vessels.

In 1868 Johnson (140) explained shock on the basis of contraction of arteries preventing return of blood to the heart.

In 1869 Verneuil (140) thought the previous state of the vital organs affects the probability of shock.

In 1870 Fischer (67) in his paper "Uber Den Shock" made the

classical description of shock which is still accepted today. He found that in shock the arteries were contracted and the heart empty. He thought the cause of death was reflex, and opposed operation on a man in shock. He made four conclusions; (1) the higher on the limb or trunk the injury is, the lighter the shock, (2) the more sudden and heavy the blood-loss thru the injury, the heavier the stage of shock, (3) individuals vary in their response to injury, and (4) the more blunt, larger area, and more powerful the force of injury, the sooner the shock.

In 1870 Clark (31) contradicted Goltz's view. He thought the simultaneous arrest of respiration and circulation was a reflex through the gastric and pulmonic plexuses of the vagus. He also considered shock and hemorrhage to be the same thing.

In 1875 Landois (140) advocated saline in shock. He thought blood transfusions were dangerous due to the likelihood of hemolysis.

In 1881 Jordan (36) said that with unimpaired cardiac action shock is impossible. He thought that anesthesia diminished the possibility of shock. For therapy he used external heat, transfusion, and cardiac puncture.

In 1883 Savory (31) said that syncope was shock in miniature.

In 1885 Groeningen (36) opposed the nervous reflex theory of shock of Goltz and Fischer.

In 1891 Lane (160) said "After an animal had sustained a loss of blood sufficient to terminate its life, there was left in the blood vascular system enough hemoglobin to sustain life, if only

enough fluid be added to keep it in circulation." He said, "intravenous saline works clinically after hemorrhage."

In 1893 Malcolm (160) found that the arteries were contracted in shock.

In 1893 Brown-Sequard (36) thought that adrenalectomized guinea pigs in shock responded to transfusions because the blood contained normal adrenal products.

In 1893 Robson (140) used four pints of normal saline intravenously in a case of post-operative shock and the patient recovered.

In 1894 Sherrington (140) said shock is due to "apoplasia."

In 1895 Warren (160) said "The condition the surgeon has to deal with is exhaustion and rest is needed for repair." In order to lessen the chance of shock he avoided prolonged exposure and handling of the intestines. For treatment he elevated the foot of the bed, bandaged the extremities, gave fluids by intravenous and enema routes, kept the patient quiet and gave morphine, and said some cardiac stimulants might be used, e.g. digitalis, coffee, nitro-glycerine, strychnine, ammonia, etc.

In 1896 Da Costa (42) said "Shock is a sudden depression of the vital powers arising from an injury or a profound emotion, acting on the nerve-centers and inducing vasomotor paresis, the blood accumulating in the abdominal vessels."

In 1897 Crile said (36) "shock is caused more by trauma to richly innervated areas, and the more intense the trauma, the more rapid the shock...hemorrhage and asphyxia predispose." He concluded

that shock was due to exhaustion and the main part was impairment of the vasomotor mechanism.

In 1898 Hill (83) experimented with rabbits. He found that when they were hung feet down they get syncope and hung head down they did not get syncope. He concluded that the lowered head position would therefore be beneficial in preventing shock, the process being cerebral anemia.

In 1899 Rhombery (140) suggested that toxic shock was based on injection of various organisms. He used intravenous salt solution for treatment.

In 1899 Crile (37) found that there was an increased peripheral venous pressure in shock. He found that injections of suprarenal extracts raise the central blood pressure. He noted that in shock there is a rise in blood pressure followed by a fall. He concluded, "shock is due to failure of the vasomotor center."

In 1904 Vale (156) said "Shock results from an overwhelming impression on the nervous system, either physical or mental, arresting more or less completely the functions of every cell in the body. There results an outpouring of lymph into the tissues in excess of normal and consequent inspissation of the blood...the enfeebled heart is largely secondary to the decreased blood pressure."

In 1905 Malcolm (108) said "the renal arteries are constricted in shock," and concluded that this was an example of the condition present in the rest of the body.

In 1907 Malcolm (109) said "In the large and in the small

vessels there is a lowered blood pressure and contraction, not relaxation, of the vessels concerned...fluid content of blood is less by squeezing serum into tissues...larger arteries and veins in central part of the body are fuller than normal."

In 1907 Boise (20) advanced his theory of cardiac collapse. Based on experiments curing shock by *veratrum viride*, a powerful heart sedative, in which he prevented shock by its use, Boise said "I am therefore confirmed in my belief that the circulatory conditions of shock are essentially and primarily a condition of tonic or spasmodic contraction of the heart, with probably coexistent contraction of the arterioles."

In 1907 Porter (130) said "We have not been able to find reliable instances in which the stimulation of afferent nerves produced a significant fall of blood pressure in the normal animal." He further stated, "The loss of blood not only is accompanied by a fall in blood pressure, but it deprives bulbar cells of oxygen."

In 1908 Porter (131) stated "Vasomotor cells are not exhausted nor depressed in the symptom complex termed shock."

In 1908 Meltzer (118) stated "Surgical shock differs from traumatic only in slower development. Possibly the pathologic state preceding the operation, the anesthesia, and the loss of blood combine to obscure the sharp outlines of shock as seen in purely traumatic cases...I venture the assumption that the various injuries which are capable of bringing on shock, do so by favoring the development of the inhibitory side of all the functions of the

body...this is the primary mechanism only, and later secondary effects occur."

In 1908 Henderson (88), working on dogs, thought shock depended upon the rate of respiration. He stated "The hypothesis is presented that acapnia (decrease in carbon dioxide in the blood and tissues resulting from hyperpnea and from exhalation of carbon dioxide from exposed viscera) is the cause of surgical shock...there is a lack of carbon dioxide and the heart rate increases up to the point of cardiac tetanus and death results."

In 1910 Malcolm (110) said, "I would argue that as a state of shock develops, there arises an intense and increasing stimulus to contraction of the vascular system, which in advanced cases may give rise to a low blood pressure from overaction of the heart." He advocated the acapnia theory.

In 1910 Hill (85) said "Shock is caused by a paralysis of the synapses by a widespread injury which causes a defective transmission at these points...nervous shock is primary...fall of blood pressure is secondary to (1) general relaxation of the body, and (2) hemorrhage and exhaustion...bandaging the limbs, pressure on the abdomen, administration of oxygen, and transfusion of saline is the appropriate treatment, the object being to maintain the circulation, which allows the synapses to recover."

In 1910 Dale (43) said "The symptoms of anaphylactic shock are much the same as that due to histamine injection--perhaps it is the cause of shock."

In 1912 Gray (77) studied shock by clinical observations of surgery. His observations lead him to state "We stress that (1) the center is not fatigued, and (2) that low blood pressure is by no means an essential feature of surgical shock."

In 1913 Short (142) reviewed the theories of the day and advanced his own ideas. Concerning the Crile-Mummery theory of vasomotor center exhaustion, he said "The arteries are contracted and the vasomotor center is not exhausted." Regarding Yandell Henderson's acaphnia theory he said "Acaphnia is not present in surgical shock, however acaphnia may cause a similar situation." Of the Boise theory of primary cardiac spasm he said "The heart still responds excellently after saline transfusion so therefore the heart is still functioning normally." He dismissed Meltzer's theory of inhibition by saying "This theory is an abandonment of the problem." He continued--"Oligemia, degenerative changes of the nerve cells, and loss of chromaffine substance from the supra-renals is yet to be accounted for. The most probable cause of shock in the writer's opinion is oligemia, induced by loss of fluid partly into the injured area, and partly through the capillaries all over the body in consequence of reflex vaso-constriction due to stimulation of the pressor afferent nerves."

In 1913 Seelig (141) found that sodium bicarbonate solution injected into shocked animals increased the blood pressure but there was no change in heart rate. He said, "Since none of the factors of bulk, hypertonicity, alkalinity, or free carbon dioxide gas

showed itself the sole cause of the pressor effect of sodium bicarbonate, we were forced by exclusion to assume that this salt acts specifically on the heart muscle."

In 1913 Abel (31) found that supplyin^g of red cells was important in the treatment of shock due to hemorrhage, for oxygen carrying powers were needed.

In 1914 Janeway (96) opposed the acapnia theory. He said there was a splanchnic trapping of blood, and in dogs increased intra-thoracic pressure caused shock. "The all important factor in the development of shock is loss of vasomotor control...the loss of control and its maintainence is never caused by acapnia or central nervous system exhaustion, but, aside from afferent impulses more especially splanchnic sensory impulses which may have initiated the shock and contributed to it, the loss of control was always due to local peripheral causes, which in our work were mechanical obstruction, lows of blood, and trauma to viscera."

In 1915 Johnson (97) enumerated the exciting causes from the surgeon's standpoint to be (1) inadequate preparation of the patient physically and nervously for the operation, (2) excessive blood letting, and (3) excessive surgical trauma. The exciting causes from the anesthetist's side according to Johnson were, (1) too light anesthesia during the severe surgical manipulations, (2) long-continued strain on the respiratory apparatus by partial respiratory obstruction, (3) chilling, (4) a bad position of the patient during anesthesia, such as the high inverted position or sitting posture, and (5) con-

tinuously maintained intrathoracic pressure in excess of 15 to 20 mm Hg. He said "measures to be effective must lie, not so much in treatment, as in prevention of shock, since when the shock is fully developed, active treatment is of little avail."

In 1915 Mann (112) said "Shock is due to a loss of circulating fluid. It is not due to any primary impairment of the vasomotor center...the loss is local at the site of trauma and is similar to the accumulation of fluid in any other irritated area, e.g. in inflammation...the nervous system is not involved...it is grave when the viscera are exposed for that is a greater vascular area."

In 1915 Corbett (34) said that shock was due to adrenal exhaustion and oligemia. He was referring to the adrenal medulla.

In 1915 Janeway (96) considered there to occur a failure of the venopressor mechanism. This was based on observations that vasodilatation occurred in shock.

In 1915 Morison (125) said "The weight of an isolated loop of gut is increased in shock, a fact interpreted to mean loss of local vascular tone. Our evidence indicated loss of venous tone which would predicate failure of the veno-pressor mechanism and a stagnation of venous blood...experiments also show a decreased rate of flow in shock."

In 1917 Mann (113) thought there were many possible causes of shock. He said "Some of the endocrine glands, particularly the supra-renals, are factors in some cases of shock; but it is very difficult to determine to what degree they participate as primary

active agents in producing the state, or how much they are affected by the low blood pressure and the changes incident to the condition itself."

In 1917 Cannon (27) said "The heart itself is not defective in the shocked individual, as can be shown experimentally! In regard to the vasomotor factor he said, "The depressor effects prove that some tonic activity of the center is still present, for otherwise its action could not be depressed; and the pressor responses reveal that the center is still capable of increased action." He concluded that the vasomotor center is not exhausted but that it might be depressed.

In 1917 Porter (132) found that carbon dioxide was beneficial in treating shock but for a different reason than Henderson offered. He said, "Carbon dioxide inhalation increases respiration and so increases venous return through a pumping effect on the large vessels of the thorax and abdomen."

In 1917 Porter (134), concluding from his observations on shock at the front, said that (1) the blood pressure is not lowered under a barrage of fire, and (2) shock is not immediate but develops some time after the injury, and therefore that it was not neurogenic. He also noted that shock often followed fracture of the long bones and concluded that shock was due to fat embolism. He found that carbon dioxide raised diastolic pressure and stated, "I believe it would be of advantage to use carbon dioxide during operations."

Bisell (12) in the same year concluded also that shock was due

to fat embolism.

In 1917 Gesell (76) studied the volume flow of blood through the submaxillary gland. He concluded, in shock "the initial fall in basal flow of blood was very much more rapid than the accompanying fall of blood pressure...there is increased viscosity of blood augmenting the effects of the decreased blood pressure...the initial fall of blood pressure causes the greatest decreased volume of flow." He stated that there probably existed both an initiating and a sustaining factor.

In 1917 Gasser (74) studied the effect of acacia on blood volume and stated, "High blood pressure in adrenalin shock causes filtration but the fluid returns when the pressure falls and polycythemia only remains permanent when the decreased supply to the tissues has resulted in damage...the possibility that acacia acts as a calcium salt in decreasing the permeability of the vessels is worthy of consideration."

In 1917 Santy (31) said that war-wound shock usually developed sometime after injury, which favored the toxemic theory.

In 1918 Cannon (29) stated "The development of a low blood pressure after muscle injury was ~~proved~~ not to be due to loss of blood from the systemic circulation."

In 1918 Erlanger (59) said "Shock supervenes in consequence of extensive tissue damage not necessarily traumatic in origin." His explanation of the mechanism of shock was; "Extensive trauma causes extensive local transudation of plasma, which, together with

primary hemorrhage, materially reduces the blood volume, and thus leads to general vasoconstriction which is enhanced reflexly by pain. The blood stream is thus slowed to the point of damaging the cells, and of starting general transudation. The arterial pressure as a result eventually becomes so slow that the vasoconstrictor center suffers and the arterial pressure falls still further. At the same time alkaline reserve is diminished, possibly through the incomplete oxidation of metabolites. Thus a series of vicious cycles is started, the outcome of which is 'shock'." This explanation of the mechanism is much the same as that of today.

In 1918 Guthrie (78) recorded some observations on shock and concluded, "Evidences point to a decreased arterial and increased venous blood volume in shock, and derrangement of the veno-motor mechanism may have an important causal relation to the condition."

In 1918 Mann (114) reported on some experiments made on dogs in which he found that "Experiments show that a circulatory impairment following obstruction of the venous return from the four limbs of an etherized animal is sufficient to produce the signs of shock."

In 1918 Wiggers (161) stated "The concentration of blood in shock, and not in hemorrhage, may be diagnostic...the venous pressure drops...it is therefore important that the state of the venous pressure should be carefully followed in suspected cases of shock... the Hooker apparatus is very efficient." In the line of therapy he advocated vasoconstrictor drugs e.g. epinephrin to overcome the reduced peripheral resistance he considered present, and to replenish

the deficient venous return by: intravenous normal saline with gum acacia as suggested by Bayliss, intravenous glucose solution as suggested by Erlanger, and carbon dioxide inhalation which increases respiration and pumps blood as suggested by Porter.

In 1918 Henderson (92) reported "De-innervation does not change venous pressure, indicating the existence of a veno-pressor mechanism distinct from vasomotor nervous regulation and consisting of a peripheral chemical control, largely through variations in the carbon dioxide content of the venous blood, over venous pressure and volume of venous return." He concluded "Therefore acapnia causes decreased venous return which produces shock."

In 1918 Wright (166) stated "Acidosis is due to decreased volume flow of blood and the accumulation of metabolic acidic products, and acid-intoxication is produced...hemorrhage, violent muscular contractions, trauma, anesthesia, gas gangrene, cholera, all are associated with acidosis through the decreased volume flow of blood." For treatment he used warming up of the patient, and the injection intravenously of alkali recommended by Cannon. He said too rapid warming may be perilous to life for it caused "a too rapid washing of muscle acid into the blood."

In 1918 McEllroy (116) said "In the type of experimental shock studied, acidosis was not the cause but one of the many secondary changes associated with the condition...injection of sodium bicarbonate into animals in shock was without beneficial action, although the alkali reserve was restored."

In 1918 Bayliss (6) advocated 6% gum acacia in .9% saline intravenously, stating "Unless hemorrhage has led to the loss of more than half of the total blood, there is no obvious advantage of blood over that of gum, provided that the gum is introduced slowly."

In 1918 Wiggers (161) stated, "Before the state of shock has progressed very far and while the circulatory condition is still amenable to therapeutic measures, the venous pressure has begun to decrease." He suggested intravenous saline and acacia.

In 1918 the Special Committee (144.5) for the study of "The Nature and Treatment of Wound Shock and Allied Conditions," made several reports, the contents of which were: it seemed highly improbable that shock was due either to (1) exhaustion of the vasomotor center, (2) adrenal-medullary deficiency, (3) acidosis, (4) acapnia, or (5) fat embolism. They thought it quite probable that a toxic factor, perhaps histamine, combined with loss of plasma or blood, caused a reduction in the circulating volume, which impaired filling of the heart and its output, and that this was the cause of the progressive lowering of arterial pressure and eventual death through asphyxia.

In 1918 Quenu (140) agreed with the toxemia theory of shock with toxin coming from traumatized tissues. He said the arterioles were constricted and thought the phenomena of shock and hemorrhage were identical.

In 1919 Cowell (35), in comparing wound and post-operative shock, said there was primary wound and surgical shock. "The bulk

of the cases of surgical shock, however, correspond to the common variety of wound shock--i.e. the secondary shock--the pressure falling towards the end of the operation or even after the patient is returned to bed. Undue anxiety, chilling, pre-existing bacterial toxemia, or hemorrhage are all pre-operative factors...during operation there is heat loss, anesthesia, hemorrhage, and trauma which contribute...any vasomotor disturbances that may be detected are transitory and of infinitely less value than the loss and concentration of the circulating fluid." He thought secondary shock was mainly preventable, especially that occurring post-operatively.

In 1919 Kruse (101) said he disapproved of the use of acacia, stating "Acacia is tolerated by normal animals but in those reduced by hemorrhage acacia is not tolerated, showing irregularities of the heart and no improvement of blood pressure until blood, saline, dextrose, or sucrose are subsequently injected." In conclusion he stated, "Pharmacologic evidence does not support the use of acacia in man."

In 1920 Aub (4) stated "There is a marked decrease in the oxygen content of the venous blood in the early stages of shock in experimental animals before blood pressure had begun to fall."

In 1920 Raymond (36) stated "In dogs traumatized under ether anesthesia there was apparently no correlation between alkaline reserve and the state of shock, and the animal's condition could not be gauged by its alkaline reserve...intravenous N/4 HCl and isotonic sodium acid phosphate did not produce shock or anything resembling it."

In 1921 Crile (38), from his studies of surgical shock starting in 1897, presented the shockless operative technique of "anoci-association." He thought shock was really exhaustion due to excess stimulation and increased function. He considered the conditions identical caused by surgery, trauma, toxins, anaphylaxis, drugs, exhaustion, starvation, hemorrhage, cold, inhalation anesthetics, etc. "The cytologic changes, however caused are due to intracellular acidosis which interferes with intracellular respiration--life itself. This causes impaired mental action and impaired muscle action and so less heat production and decreased temperature. Relaxed muscles including the vascular system produce decreased blood pressure. Internal respiration is interfered with by secondary causes, e.g. anemia. If intracellular exhaustion is not complete then transfusion cures shock. If intracellular exhaustion is complete, despite a full pulse created by transfusion, the improvement is only apparent." He considered post-operative shock preventable by using an operative technique which minimizes shock producing factors, e.g. using nitrous oxide anesthesia, lessening trauma, and anesthetizing each layer by local injection of novocaine before cutting it, thus lessening the nerve impulses stimulated.

In 1921 Cannon (30) concluded the initiating factor to be toxic substance in the traumatized area. "Although proof is still lacking that a substance, like histamine in character, is actually given off into the blood stream when the tissues are severely damaged, the effects of local tissue injury (influencing the rest of the body

solely through the circulation) and the effects induced by histamine are so similar that the supposition has a high degree of probability."

In 1922 Cannon (31) concluded that the formation of a vicious circle was the sustaining factor in shock. He considered morphine to be of value in helping to prevent the establishment of this vicious circle. "Possibly morphine, by reducing activity of the tissues, lessens their demand for oxygen and thus compensates for the smaller supply of oxygen in the sluggish blood flow."

In 1922 Henderson (93) stated "Through the loss of red blood cells, hemorrhage is a form of asphyxia...relative acidosis occurs in shock due to hemorrhage as the respiration is increased due to asphyxia, and the carbon dioxide is washed out thus decreasing alkaline reserve."

In 1923 McIver (117) did some experimental work on dogs concluding "This evidence suggests that some substance capable of producing shock is taken up by the circulation from a traumatized area."

In 1923 Cannon (31) published a monograph on shock discussing the various theories as to the etiology of shock. He did not agree that the adrenal glands were involved.

In 1924 Gatch (75) found a great deal more blood lost in operations than was thought, in sponges etc. He thought this direct loss was very important in causing post-operative shock.

In 1924 Krogh (100) studied the normal function of capillaries. He found that there was some "X" substance which caused contraction of the capillaries. He also found that blood flow was decreased by adrenalin due to constriction of arterioles.

In 1926 Craddock (123) found that diathermy was beneficial in a case of shock. This was tried due to the value found by external heat.

In 1927 Randall (135) reported, "In cases with a crushed extremity, shock supervenes usually half an hour or so after removal of the tourniquet." He used glucose for shock and made it available to the body with insulin. He considered the benefit noted due to the fact that glucose was used for burning to supply energy.

In 1927 Blalock (13) said "Shock is a group of symptoms." He studied shock through repeated hemorrhages and found that there was a decreased volume of blood flow resulting in decreased minute cardiac output and diminished caliber of peripheral arteries. "It is believed the other circulatory effects are secondary...blood pressure is inadequate as a guide to the state of incipient shock." In regard to therapy he said, "drugs are relatively useless as compared to those measures which tend to restore blood volume."

In 1927 Phemister (129) reported some experiments which did not support the traumatic toxemia theory. "Blood and fluid loss in the traumatized area is more than must be withdrawn to produce shock experimentally."

In 1928 Landis (104) studied capillary permeability and concluded "Since a reduction of the circulation leads to tissue anoxemia and an increase in permeability of the capillaries, perhaps vasoconstriction with the attendant reduction of blood flow to large areas might be the mechanism for this decrease of blood volume."

In 1929 Moore (124) stated, "It is quite evident that the shocked animal does not lose its blood into a dilated spleen...there is also very marked splanchnic vasoconstriction which disproves the recent idea that the failure of adrenalin to restore normal blood pressure in clinical shock points towards the existence of vasomotor paralysis."

In 1930 Blalock (14) found the oxygen content of blood from traumatized areas is higher than normal. "These observations suggest a local accumulation of blood at the site of trauma to a large area such as intestinal tract or an extremity, and are evidence against the action of a histamine like substance that produces a general bodily effect."

In 1930 Atchley (3) stated, "Medical shock is a condition which is the same as surgical shock only it is reached differently...the treatment of shock is more or less independent of its cause. Whether it is due to trauma, toxemia, hemorrhage, or anhydremia, the physiologic problem is the same; namely a disproportion between blood volume and vascular bed--primary decreased blood volume from hemorrhage or fluid loss--increased vascular bed from capillary dilatation." He used first 50cc 50% glucose, then 1000cc normal saline, then transfusion. He thought no vasoconstrictors are indicated.

In 1930 Blalock (15) again reported that his experiments offer no evidence of a toxic factor. "There was a sufficient loss of blood volume into the traumatized area in all these experiments to account for the reduction in blood pressure, and more plasma than cells accounting for hemoconcentration."

In 1932 Moon (119) stated, "Products absorbed from injured tissue produce shock by causing dilatation and increased permeability of capillaries and venules...shock syndrome is accompanied by gross and microscopic changes opposite those produced by hemorrhage. The changes include dilatation and engorgement of capillaries and venules, permeability of capillary walls as indicated by petechial hemorrhages and edema, and frequently effusion into serous cavities."

In 1933 Swingle (148) experimented on adrenal cortex insufficiency and stated, "The signs and symptoms of adrenal insufficiency and of trauma or secondary shock, are possibly due to one and the same thing, i.e. failure of the blood volume and blood diluting regulatory mechanism, the adrenal cortex...the idea that the adrenal cortical hormone might prove of benefit in the treatment of human traumatic shock is advanced."

1933 Freeman (70), because the factors recognized to be significant in producing shock, such as cold, pain, fear, asphyxia, age, and dehydration, are also stimulants of the sympathetic nervous system, suggested that the reduced volume of shock, where it could not be accounted for by hemorrhage or transudation, might be the result of sympathetic hyperactivity. Based on this hypothesis, experimental work on cats showed "decreased blood volume resulted from prolonged hyperactivity of the sympathetic nervous system."

1933 Freeman (71) pointed out that in adrenal insufficiency the blood sugar is low, and that in traumatic shock it is normal or elevated. He said Swingle made entirely too light of this difference.

He stated, "Cortex extract probably helps shock in adrenalectomized dogs--so does glucose help insulin coma but no one said insulin coma and traumatic shock are the same." He concluded, "There is no evidence convincing one that deficiency of cortex hormone and traumatic shock have a common etiology or that cortical hormone is of benefit in treatment of shock."

In 1933 Moon (120) observed that the circulatory changes and degree of hemoconcentration due to trauma, burns, metabolic toxins, certain drug poisonings, intestinal obstruction, pancreatitis, perforated ulcer, and severe infections were the same, and considered them due to the same mechanism. He noted "increased concentration of blood is a regular feature of traumatic and surgical shock... Observations on the concentration of blood should be diagnostic of the severity of shock."

In 1934 Holt (86) found in his experiments that "Blood collected from traumatized limbs and injected into another animal produces no changes typical of shock. Therefore we can demonstrate no toxic substance."

In 1934 Cannon (32) defended his theory by the statement, "The toxemia theory is opposed by negative evidence but no positive evidence...One cannot exclude the toxemia theory on negative evidence alone."

In 1934 Henderson (94) re-emphasized his acapnia theory by stating, "Hemorrhage is a form of asphyxia--use carbon dioxide and oxygen for treatment...Surgical and traumatic shock produce depression

and finally failure of circulation which produces acapnia, acarbia, and pseudo-acidosis. Carbon dioxide and oxygen stimulate respiration and promote venous return through increasing the effective difference of pressure between the tissues of the body and the thorax."

In 1935 Slome (144) discredited the toxemia theory by stating: "(1) the quantity of depressor substance in the traumatized muscle is inadequate to produce shock, (2) Occlusion of venous return from a traumatized limb does not prevent shock, (3) there is no evidence of a toxic substance in the area of trauma or in general circulation in shocked state, (4) histamine poisoning produces different changes." He concludes, "Experimental findings suggest that the nervous factor is an important causative agent in traumatic shock, reinforcing the effect of fluid loss at the site of trauma."

In 1935 Roome (138) found that "fluid obtained from traumatized and normal limbs of dogs by hydraulic press was injected into other animals. There was no shock. This invalidates the toxic theory."

In 1935 O'Shaughnessy (128) stated, "Toxins due to the elaboration of histamine, or any other depressor substance manufactured in the traumatized area, plays no part in the syndrome of traumatic shock. Local fluid loss and discharge of nociceptive nervous stimuli we regard as the etiologic agents. The nervous factor dominates." As a result of this view they advocated local anesthesia, or spinal anesthesia for therapy. They considered intravenous therapy of no benefit.

In 1936 Moon (12), in studying the mechanism of death following

intestinal obstruction, found the physiologic disturbances to be the same as in the shock syndrome following trauma. "The pathology was marked distention and engorgement of capillaries and venules in the viscera, edema and ecchymoses of the lungs and gastrointestinal mucosa, and effusions into serous cavities." He said that there was capillary injury as shown by "capillary hemorrhages, the formation of edema fluid of high protein content, and the rapidity with which colloidal dyes escape from blood into the tissues." He considered the cause to be toxic.

In 1936 Freeman (73) found "The volume flow of blood through the hand in clinical cases of shock was markedly decreased." He said the oxygen content of venous blood was decreased due to less circulation and no decrease in the use of oxygen. "The reduced flow in the hand is probably a condition which is general through the body as there is peripheral and splanchnic constriction also." He said adrenalin was not good therapy for it further decreases blood supply to the tissue. "Proper therapy is more blood or blood substitutes."

In 1936 Moon (122) described shock by saying "Shock is a circulatory deficiency not cardiac or vasomotor in origin, characterized by a decreased volume of blood and cardiac output and by hemoconcentration. Other physiologic disturbances occur such as decreased blood pressure, decreased basal metabolic rate, decreased renal excretion and increased heart rate. In advanced cases coagulability and oxygen of blood are decreased, chlorides are below normal, and

non protein nitrogen is increased. Other things not always present are decreased alkali reserve, and subnormal temperature in all but burn shock. The respiratory rate is increased, and vomiting and diarrhea usually is associated with severe shock. Vomitus, feces, and urine often contain albumin. Leukocytosis sometimes occurs." Concerning pathology he said, "The superficial veins are collapsed and blood content is less...blood is dark and thick and failed to clot...serous surfaces are diffusely congested...in severe cases there are ecchymoses and cavities contain blood tinged fluid... bowels are atonic and distended...mesenteric vessels are engorged... mucosae are congested, edematous, and often contain ecchymoses, and appear like purple velvet...lungs are intensely congested...microscopically the capillaries and venules are dilated and packed with red blood cells...there is parenchymous degeneration of the organs... The adrenals are congested and often vacuolation of the cortical cells is present which Zemer said was due to physiologic demand for cortical hormone." Some say shock is due to adrenal insufficiency but Moon said that occurs several days after extirpation and so post-operative shock cannot be due to that for it occurs much earlier. He considered the cause of shock to be toxic absorption producing permeability of capillaries.

In 1936 Fender (65) worked with crossed blood experiments. He reports, "We can demonstrate the presence of no depressor substance in blood of traumatized animals."

In 1937 Harkins (80) stated, "The calculated gain in fluid

content of the injured area closely approximates the reduction of blood volume."

In 1937 Dragstedt (52) was unable to demonstrate the presence of a depressor substance.

In 1939 Allen (1) believed a toxic factor present and suggested the term "Histotoxicosis."

In 1939 Davis (46) studied regional distribution of blood in secondary shock. He stated that histamine was not the cause of shock for in histamine poisoning the blood was more in the periphery and lungs in contrast to traumatic shock where the splanchnics were constricted and there was more blood at the area of trauma, which blood may be in dilated vessels or extra-vascular spaces of traumatized tissue. He stated, "In traumatic shock there is at once established a point of excessive permeability in the vascular system at the site of trauma. Consequently the effect of splanchnic vasoconstriction is to force more blood into the area of trauma and beyond the vasomotor control and so a vicious circle is established." He said he has "direct experimental evidence against splanchnic pooling of blood in traumatic and hemorrhagic shock."

In 1940 Fantus (64) said to use blood transfusions for therapy or acacia if no blood is available. He said epinephrine helps in the final vasodilatation. He suggested that fluids other than blood be injected intravenously at 110 degrees F. in order to help warm the patient.

In 1940 Kendrick (98) experimented and reported, "Injection of

blood from limbs traumatized ~~forty-five~~ minutes into another animal produced significantly lowered blood pressure in ~~forty~~ minutes and death in a few hours." From this he concludes, "This is suggestive but not conclusive evidence for the toxemia theory of shock."

In 1940 Davis (47) studied the pathology of shock in man. He noted "marked vascular congestion of the splanchnic area...The extent of vasodilatation is difficult to determine--in operations within the peritoneal cavity it is chiefly splanchnic...the blood loss in the operations was not sufficient to cause shock...in shock there is vasodilatation and reduced blood volume."

In 1940 Boothby, (21) stated that capillary dilatation occurs first and is compensated for by arterial constriction and that low blood pressure is a sign of decompensation rather than early shock. Treatment is more effective in early stages before the vicious circle has been established. At the Mayo Clinic they use prophylactically (1) careful but rapid surgical technique, (2) heat externally and internally by warm gastric and colonic irrigations, (3) control of fear and pain pre-operatively by morphine, (4) pre-operative correction of dehydration, (5) correction of secondary anemia pre-operatively in selective surgical cases, and (6) oxygen inhalation, 100%. For therapy of existing shock they use inhalation of 100%

In 1941 Koster (99) studied the relation of surgical shock and the fall of blood pressure in spinal anesthesia and found "the fall

of blood pressure in spinal anesthesia is not shock for there is hemodilution and so it is no argument against spinal anesthesia."

In 1941 Tenery (155) said that extensive burns are followed by primary shock, hemoconcentration, and infection, but with adequate therapy these can be controlled and the toxic stage of burns, which occurs later, will not develop. Intravenous saline and plasma should be used for he says they prevent electrolytic changes.

In 1941 Dunphy (54) studied the pathology of experimental shock. He found that there was a compensatory vasoconstriction due to loss of blood volume by hemorrhage or shock, and that if persistent eventually there is evidence of generalized capillary injury and loss of fluids in the viscera perhaps due to ischemia. The fluid loss at the site of injury he considered the initiating factor in reduction of blood volume and hemoconcentration. Regarding further development of the state he said, "In the late stages, either as a consequence of prolonged ischemia, adrenal insufficiency, the absorption of hypothetical toxins or factors not yet considered, there develops generalized capillary injury and loss of fluid throughout the viscera particularly marked in the lungs, liver, kidneys, and gastrointestinal tract. Thus, the final pathologic picture is quite similar to that seen following poisoning, infection, anaphylactic shock, and other states in which capillary injury occurs." He further stated, "If late changes were due to anoxemia due to reduced blood supply they should be able to be prevented by maintaining blood volume at normal." Such has been his experience. He believes

plasma to be the most effective form not only in restoring the volume, "but also in ameliorating the late pathologic changes of shock."

In 1941 Davis (48) studied dehydration shock produced by burns, trauma, plasmapheresis, and dehydration. These lead to deficient oxygenation of the body tissues, which are followed by dilatation and increase in the number of functioning capillaries, which permit an increased diffusion of oxygen from the blood and increased permeability and dilatation resulting from the local effect of poorly oxygenated blood.

In 1941 Blalock (18) found that significant elevations of temperature cause more disastrous effects than do depressions of similar degree, i.e. they shorten the period of survival of shocked animals. He also found (19) that decreased blood volume with the resulting anoxia is responsible for most of the tissue damage in shock.

In 1941 Davis (49) said that oxygen should be regarded merely as a subsidiary form of treatment and only should be used until blood or substitutes can be administered.

In 1941 Besser (8) said that although there is considerable evidence that the adrenal cortex acts as a protective mechanism against shock and beneficial effects have been reported in surgical shock by cortical hormone therapy, he found Desoxycorticosterone acetate to be of little significant value in preventing shock when compared with controls. He said there is the possibility, however,

that a more active steroid, corticosterone, may prove of value. He found that (9) stored dextrose-citrate plasma was efficacious in treating a series of patients manifesting shock associated with general surgical operations.

In July, 1941, Baird (5) said factors besides hemorrhage contributing to shock, are sweating, loss of plasma from exposed surfaces, pooling of blood in damaged areas, anesthesia, infection, and particularly the disease for which the operation is performed.

In 1941 Blalock (19) discussed prevention and treatment, stating that intravenous fluid is the most important single form of therapy. The most advantageous fluid is plasma and serum. The advantages listed by him of plasma over blood are (1) it can be stored cold for months, (2) it can be kept a number of days at room temperature, (3) it is easier transported, (4) no typing is necessary and there are no severe reactions, (5) it is ready for instant use, and (6) it does not add to the concentration of the red blood cells, hemoconcentration being present usually. Regarding adrenal cortical extract he said, "reports are encouraging but not enough to rate adrenal cortical extract as one of the more valuable agencies in therapy."

In January, 1942 Wiggers (163) concluded that information was inadequate in support of any one theory and thought that serum or plasma was the best therapy and if given soon enough prevented the development of shock.

In March, 1942 Hill (82) advocates the use of dessicated plasma for the prevention and treatment of shock. He said dessicated

plasma was ideal for it could be easily prepared in four times normal concentration, could be made by mass production, and was easily prepared by freezing and dessication by electricity. The advantages he cited were (1) it preserves proteins without deterioration, (2) it is rapidly soluble, (3) it will not support bacterial growth, (4) it is in reduced bulk, and (5) there is no Fibrin precipitation and no tendency for such after it is dissolved.

Definition

Shock is a symptom complex and not a disease. Early writings speak of "draining of the vital fluid," "loss of animal and organic powers," "destruction of the great nervous power," "complete depression of all vital functions," "commotio cerebri," etc.

In 1795 Latta (31) first applied the term shock loosely to diverse conditions associated with sudden weakness, fainting or unconsciousness, and sudden death.

Gross, (123) in 1872 said "shock is a depression of vital powers, induced suddenly by external injury, and essentially dependent upon loss on innervation."

The Lockhart-Mummery (126) definition of 1910 was shock is "a condition of lowered blood pressure resulting from exhaustion of the vasomotor centers."

Many writers defined shock according to their theory as to its cause. A good descriptive definition was made by Moon (123) in 1936--"A circulatory deficiency, neither cardiac nor vasomotor in

origin, characterized by decreased blood volume, decreased cardiac output (volume flow of blood) and by hemoconcentration."

Freeman, (140) in 1940, included his theory in the definition, "The clinical condition characterized by progressive loss of circulating blood volume, brought about by the tissue anoxia which results from inadequate circulation."

Harkins, (81) in 1941, said it was "a progressive vasoconstrictive oligemic anoxia," and made a detailed descriptive definition, "An oligemia initiated by traumatic local fluid loss, either whole blood, plasma, or both; accompanied by decreased cardiac output, diminished volume flow, lowered venous pressure, decreased oxygen consumption, arteriolar vasoconstriction, acapnia, and secondary blood pressure fall; and perpetuated by a summation of these factors and possibly hyperpotassemia, increased generalized capillary permeability, anoxia, action of tissue metabolites and deficiency of adrenal cortical hormone."

In 1942 Wiggers said, (163) "Shock is a syndrome resulting from depression of many functions, but in which reduction of the effective circulating volume and blood pressure are of basic importance and in which impairment of the circulation steadily progresses until it eventuates in a state of irreversible failure."

The Theories of Shock

As with everything for which the cause is unknown, there have been many theories advanced as to the etiology of shock. Harkins

classified the theories of shock in 1941 as follows (81):

1. Nervous
 - Vasomotor Exhaustion (really should be paralysis)
 - Mitchell, Morehouse, and Keen (1864)
 - Fischer (1870)
 - Exhaustion (really should be vasomotor exhaustion)
 - Crile (1897-1920)
 - O'Shaughnessy and Slome (1935)
 - Inhibition
 - Meltzer (1908)
2. Fat embolism
 - Bissell (1917)
 - W.T. Porter (1917)
3. Arterial vasoconstriction and capillary congestion
 - Mapother (1879)
 - Malcolm (1893-1909)
 - Starling (1918)
 - Erlanger, Gesell, and Gasser (1919)
4. Acapnia
 - Henderson (1908)
5. Acidosis
 - Cannon (1919)
6. Hyperactivity of adrenal medulla
 - Bainbridge and Trevan (1917)
 - Freeman (1933)
7. Exhaustion of adrenal medulla
 - Sweet (1918)
8. Adrenal cortical insufficiency
 - Swingle, Pfiffner, et al. (1933)
9. Traumatic toxemia
 - Cannon, Bayliss, and British Medical Research Committee (1918)
10. Traumatic metabolites giving capillary atony and tissue anoxia
 - Moon (1932-1938)
11. Local fluid loss
 - Phemister (1927-1930)
 - Blalock (1930)
12. Progressive oligemic anoxia
 - Harkins (1940)

The Vasomotor Paralysis Theory

The vasomotor paralysis theory of Mitchell (31) is that there is a "reflex paralysis" and the wound may directly destroy the vital centers." At this time there was no differentiation between

primary and secondary shock. Goltz (160) found reflex stopping of the heart and stagnation by his classic experiment of hitting the abdomen of a frog. Fischer (61) believed in vasomotor exhaustion and stagnation of blood in the splanchnic area basing his opinion largely upon the experiments of Goltz. Wallace (31) in 1917 found there was no distention of abdominal vessels when shocked men are operated upon and Malcolm (110) in 1909 found that splanchnic congestion is never observed in shock induced by an unusually severe or prolonged abdominal operation which disproved the theory. They then did not know there was reduced blood volume which could account for the reduced blood pressure. Cannon (31) said that this theory is not considered possible in primary shock but not in secondary.

Vasomotor Exhaustion Theory

The vasomotor exhaustion theory was advocated by Crile (37) in 1899 and Mummery (126) in 1905. It was referred to as the Crile-Mummery theory. Crile stated, "Surgical shock is mainly due to impairment or break-down of the vasomotor mechanism...the heart is not exhausted, and it is not the principal factor in the production of shock." Mummery concluded the same.

In 1908 Henderson (88) said the vasomotor mechanism was very active trying to compensate rather than exhausted. It was opposed in 1912 by Gray (77) who found the nerve cell changes could be caused by anoxemia and also found there was a pressor vasomotor response active which proved the vasomotor center was not exhausted.

He stated, "We stress that the center is not fatigued, and that low blood pressure is by no means an essential feature of surgical shock." In 1913 Short (142) said, "The arteries are contracted and the vasomotor center is not exhausted." Many others since have offered evidence that the vasomotor center is not exhausted, and that nerve cell changes are found but also are found in all parenchymous organs and are due to anoxemia, not nerve impulses. In 1914 Mann (111) stimulated nerve trunks and produced no shock, concluding it was not due to nervous stimulus. Forbes (68) in 1916 found that anesthesia prevents afferent sensory impulses as well as motor and so there was no basis for the statement that impulses during operations caused nerve cell changes. The Special Committee (144.5) during the first World War concluded that shock was not due to vasomotor exhaustion for nerve cell changes were those of prolonged anemia. Kurtz (102) in 1915 and Dolley (51) in 1916 stated that there were typical histological changes in nerve cells after shock and hemorrhage, and so supported the theory. Allen (2) in 1915 said the cell changes were within the range of normal variation and therefore of no significance. Mann (111) studied shock and could not produce it by prolonged electrical and mechanical stimulation of large numbers of sensory nerve fibers. He stated, "It is not due to any primary impairment of the vasomotor center." In 1914 Janeway (96) considered there to be failure of the vasomotor mechanism for he noted vasodilatation in shock. In 1917 Cannon (27) found that the vasomotor system could be both stimulated and depressed and concluded

that the vasomotor mechanism might be depressed but it was not exhausted. In 1918 Erlanger (59) found the vasomotor tone increased for several hours in shock and declined only in the later stages, concluding that the failure of the vasomotor ability is not the cause but the consequence of the low blood pressure. In 1921 Crile (38) presented the anoci-association method of surgery based on the idea that post-operative shock was based on nerve cell changes caused by excessive stimulation during operations. In 1935 O'Shaughnessy and Slome (128) stated that toxins played no part and reverted to the depressed vasomotor theory, stating, "Local fluid loss and discharge of nociceptive nervous stimuli we regard as the etiologic agents. The nervous factor dominates." The predominance of opinion, however, is that the changes in the nervous system, which is the positive evidence offered, are secondary to decreased blood pressure, and that depression of the vasomotor system has nothing to do with initiating shock.

The Inhibition Theory

The Inhibition theory of Meltzer (118) was presented in 1908. His experimentation showed that in shock there is suppression of intestinal movements which he considered due to inhibitory impulses. He concluded that the reduced sensibility was due to the same cause. Since the insensibility, general apathy, and muscular relaxation are present long before any signs of vascular or cardiac breakdown, he thought they were the essential causes, and concluded, The various injuries which are capable of bringing on shock, do so by favoring

the development of the inhibitory side of all the functions of the body...this is the primary mechanism only, and later secondary effects occur." Meltzer did not consider the decrease in blood pressure in his studies.

Cannon, (26) in 1907, said the stimulation of afferent nerves causes discharges along the sympathetic pathways which check the contractions of the alimentary tract. This explains the lack of intestinal motion noted by Meltzer according to Cannon. In 1913 Short (142) dismissed Meltzer's theory of inhibition by saying, "This theory is an abandonment of the problem." In 1918 Porter (133) said, "Manipulation of the intestine will cause in a spinal reflex a rise in threshold, i.e. an obstacle to ready passage of nerve impulses...this may account for Meltzer's noted lack of responsiveness."

Fat Embolism Theory

In 1885 Groeningen (31) said fat embolism was often mistaken for shock but that there was no excuse for it. Warthin (165) in 1913 also thought that surgeons had often mistaken fat embolism for shock. In 1917 Porter, (134) in observing shock at the front, noted that shock often followed fracture of the long bones and concluded that shock was due to fat embolism. Bissell (12) in the same year expressed the same idea.

In 1918 Simonds (143) found that when fat was injected the arterial blood pressure decreased but the venous pressure increased, is not true in shock. In 1918 Wiggers (161) concluded that neither

intravenous nor intra-arterial fat injection produced typical shock. Cannon (31) found in a study of clinical cases that there were no signs of fat in the lungs, e.g. no dyspnea, rales, etc. Crile (38) in 1921 said, "The theory fails to account for, (1) shock seen when abdominal injuries are accompanied by penetration of hollow viscera and not seen when there is no penetration, (2) shock from burns, (3) shock from head and chest injuries."

Arterial Vasoconstriction and Capillary Congestion

The theory of arterial vasoconstriction and capillary congestion was originated by Mapother (115) in 1879, who stated that the most marked physical change observed in shock was a constriction of the arterioles, with paralysis of the vasodilatation nerves. In 1910 Malcolm (110) noted that the organs were pale in shock and thought the process was one of vasoconstriction which made the blood collect in veins and plasma passed out due to increased tension, thus lowering the blood volume. This lowered the blood pressure and "starved" the vasomotor and other vital centers. He made the conclusion that there was decreased blood volume for he noted that the condition was benefited when the blood volume was increased. He failed to account for the primary vasoconstriction. In 1918 Starling (31) said there was a decreased cardiac output because there was less blood in circulation. The blood was not in abdominal veins and must be in dilated capillaries of the muscles since the skin was pale showing the blood was not there. He thought injury caused vasoconstriction and an increase in blood pressure, and since there

was decreased tone in muscle the capillaries there dilated. Less circulation and less oxygen produced acidosis and more dilatation. He also thought there might be some dilatation through stimulation of afferent nerves. The deficient venous return caused decrease in general circulation. Since tissues with no oxygen form fixed acids and therefore acidosis and more dilatation and permeability of capillaries, a vicious cycle was instituted.

Evidence against the theory is that the initial increase of blood pressure is so slight, if present at all, that it is difficult to assume so little a change would produce such a change physiologically. Cowell, (144.5) in the Special Committee reports gives three reasons why this theory is incorrect: (1) at the front the blood pressure is not over 140-160, within normal limits, (2) shock may occur in sleep when the blood pressure is low, and (3) there is no evidence that blood is collected in capillaries of the muscles. Erlanger and Gesell, (61) in 1919, reduced the circulation by creating venous stasis and noted diapedesis and reduced blood volume. In another article they report finding extreme dilatation of capillaries of the gastro-intestinal tract with solid masses of red blood cells filling them, and decreased blood volume. Since they had noted in 1917 (58) that pain stimulation and some hemorrhage might activate the vasoconstriction mechanism and decrease circulation, they concluded vasoconstriction was the mode of instigation of shock. They did not show a method of action of the initiating agent and so their theory was incompletely proved.

The Boise theory of cardiac collapse (20) probably fits in this group although Harkins does not list it. Boise thought the heart was spasmodically contracted and probably the arteries were also contracted in shock. His experiments were preventing and curing shock by the use of a powerful heart sedative.

Acapnia Theory

In 1908 Henderson (88) presented his theory of acapnia, i.e. that shock is due to decreased carbon dioxide content of the blood. This idea was conceived when, working on dogs, he believed shock depended upon the rate of respiration. He thought the lack of carbon dioxide caused increase in heart rate up to the point of cardiac tetanus and death due to decreased circulation. In 1909 he noted (89) that the circulation through the heart may be decreased sixty per cent while the blood pressure remains the same, and in 1910 expressed the opinion (90) that shock was due to decreased venous return. He thought the pain of injury, fear, and sorrow caused hyperpnea, which caused acapnia resulting in failure of the venopressor mechanism and causing venous anoxemia, tissue asphyxia, and acidosis, and finally acute oligemia. He said when the blood was stagnant in the peripheral vessels fluid passed from the blood out, due to physico-chemical changes in the tissue due to asphyxia. He considered the primary failure cardiac due to oxygen starvation of the heart. Against the theory is the well known fact that there is no pain at first in severe wounds.

Cowell (144.5) of the Special Committee said he noticed no

hyperpnea in soldiers injured at the front. Edsall (63) in 1912, said the respiration of shock was rapid and shallow and that type did not clear out carbon dioxide because of the large dead air space of man. He produced extreme hyperpnea in experimental animals and did not cause shock. Hill and Flack (84) in 1908 said the shock Henderson produced by hyperventilation was due to interference with the venous flow by mechanical influence. Janeway and Ewing (96) found the same information and also caused shock by intestinal manipulation while the carbon dioxide was being kept up to the normal level. Cannon, in 1921, (31) dis-credited the acapnia theory by stating, "(1) the pain required for hyperpnea is usually absent, (2) shock without acapnia and acapnia without shock exists, and (3) low carbon dioxide can be the result of low blood pressure, not the cause."

Acidosis Theory

The theory of acidosis was formulated by Cannon (29) and later disproved by himself (144.5). He noted that Hooker, in 1912, Gaskell, in 1880, and Bayliss, in 1901, found that small amounts of acid cause vascular relaxation. He used the information given by Patterson, in 1915, that increased hydrogen ion concentration produced by carbon dioxide caused relaxed cardiac muscle, decreased cardiac output, and increased viscosity. In 1918 Cannon (29) noted a striking improvement when sodium bicarbonate was injected intravenously into shocked animals. He theorized that acidosis caused the initial decrease in blood pressure with a consequent reduction of alkali reserve, local

relaxation of vessels, weakened cardiac contraction, and increased viscosity of blood which made the condition worse. The Special Committee, (144.5) of which Cannon was a member, found that the acidosis in experiments was much more than that present clinically. They also found that sodium bicarbonate was of no benefit therapeutically. They consoled themselves with the statement that the study of the acidosis condition showed why increased circulation and more oxygen must be obtained early for tissue.

Hyperactivity of the Adrenal Medulla Theory

The theory of hyperactivity of the adrenal medulla was suggested by Bainbridge and Trevan (4.5) in 1917. They started with the well known fact that adrenal secretion is increased during extreme emotion or pain. Experimentally they injected adrenalin into animals for twenty minutes to keep the blood pressure high. When they stopped the injection a shock state precipitated with decreased blood pressure, increased venous pressure, rapid feeble pulse, shallow respiration, and hemoconcentration. Erlanger and Gasser (59), in 1919, found the same results and believed the instigation due to extreme slowing of circulation by vasoconstriction. In 1928 Landis (104) studied capillary permeability and concluded that perhaps vasoconstriction with the attendant reduction of blood flow to large areas might lead to tissue anoxemia and cause shock. In 1933 Freeman found (70) a decrease in blood volume after prolonged hyperactivity of the sympathetic nervous system, which he considered indicating that some cases of shock might be due to sympathetic

hyperactivity.

Contradictory evidence was offered in 1917 by Henderson (91) who failed to get these results. Bedford (7.5), in 1917, found more adrenalin in the blood when the pressure was low, but Stewart (145), in 1919, found no increase of adrenalin in low blood pressure. Cannon, in 1921, (31) said the experimental production of this condition by the use of adrenalin injection could not be accepted for the amount of adrenalin used was much higher than would ever be found physiologically. More recent literature is not concerned with the theory.

Exhaustion of Adrenal Medulla Theory

Addison (31) first found that the adrenals were essential to life, and Brown-Sequard (31) noted that adrenal extirpation resulted fatally, but that blood transfusion helped the condition which he ascribed due to the content of adrenal secretion. In 1908 Lavenson reported (106) a few cases of unexplained collapse in which autopsy revealed thrombosis of both adrenal veins. In 1915 Corbett (34) noted exhaustion of the glands in trauma, ether anesthesia, and infection. In 1918 Sweet (147) found that removal of the adrenals in lower animals produced shock and concluded that adrenal medulla exhaustion is the etiology of shock.

Contradictory evidence was offered by Short (142) in 1914--he found that the adrenalin content of the glands in animals in shock is not reduced. In 1912 Hoskins (87) found that the amount of adrenalin necessary to increase blood pressure stopped gastro-

intestinal function, a condition not noted in shock. Austman (31), in 1917, removed adrenals and found that blood pressure remained normal for several hours. Mann (113), in 1917, found that total excision of the adrenals did not produce shock. The Special Committee (144.5) said this was not the cause of shock. Since then the theory has been given little thought.

Adrenal Cortical Insufficiency Theory

In 1933 Swingle (148) advanced the theory of adrenal cortical insufficiency. He said the signs and symptoms of adrenal insufficiency and of shock are very similar and possibly due to the same thing--failure of the adrenal cortex which was the blood volume and diluting regulatory mechanism. He suggested that adrenal cortical hormone might be beneficial in the treatment of shock. In the same year Freeman (71) pointed out that the experimenters made light of the difference in blood sugar in the two conditions--low in adrenal insufficiency and normal or elevated in shock. He thought their conclusion, that because cortex extract helped the condition of adrenalectomized dogs it should help shock in man, was absurd.

In 1936 Moon (121) considered the pathological changes in adrenal cortex, which had been presented as evidence of insufficiency of adrenal cortical hormone, was due secondarily to anoxemia, pointing out that there were similar changes in other organs also.

Swingle presented four more articles (149, 150, 151, & 152) which stated evidence that (1) the reduction in effective blood volume and changes in blood chemistry after adrenalectomy are similar

to those of shock and hemorrhage, (2) animals in a profound state of shock can be revived by injection of cortical extracts and some purified products, (3) adrenalectomized animals withstand less trauma and hemorrhage, (4) adrenalectomized animals regain their normal resistance if previously protected with large doses of cortical extracts, and (5) shock cannot be produced by standard methods in normal animals who receive prophylactic doses of cortical hormone. They therefore assumed that cortical hormones maintain normal capillary tone and permeability.

Wiggers (163), in 1942, considers this conclusion somewhat irrelevant in regard to shock for the evidence that shock is due to an influence on capillaries is only circumstantial.

In 1940 Selye (141.5) presented his Alarm Reaction theory in which he stated that various stimuli cause an emergency reaction in the animal and that shock is the result of the stimuli. In response the body starts counter-shock phenomena. At this time there is enlargement and increased activity of the adrenal cortex, and an increase in the production of cortin and a rise in blood chlorides are characteristic physiological counter-shock phenomena. Therefore he considers cortex hormone to be good therapy as it aids the natural physiological response to shock.

In 1941 Besser (9) said that although there was considerable evidence that the adrenal cortex acts as a protective mechanism against shock and that it helped therapeutically, he found desoxycorticosterone acetate to be of little significant value.

Blalock (19), in 1941, said that reports are encouraging but not enough to rate adrenal cortical extract as one of the more valuable forms of therapy.

Riley (137), in 1941, admitted that adrenocortical insufficiency has many similarities to shock but said complete removal of the adrenals does not produce shock in a matter of hours, but of days. He concluded that it is difficult to hypothecate a rapid response to deficiency in one condition and a slow response in another.

It has long been noted that shock responds much better to intravenous therapy early than late. This was often attributed to the effect of establishment of a vicious cycle of anoxemia. In 1942 Wiggers (163) stated that he believed it hard to consider defficient venous return as the sole cause of the irreversable circulatory failure found in profound shock. Consequently he suggested that as yet some unidentified precipitatory mechanism or several of these in association causes the final condition. The possibilities he suggested were adrenal cortex hormones, translocation of potassium, default of emergency reflex controls, vasomotor failure, myocardial depression, or lack of aortic adaptation. In conclusion we must say that the literature does not give enough evidence as to whether adrenal cortex insufficiency is the cause of shock or not.

Traumatic Toxemia Theory

The theory of traumatic toxemia was advanced by Cannon and the

Special Committee (144.5) as the result of their observations and experimentations during the first World War. They noted that shock appeared especially after injuries causing a great deal of tissue injury especially to muscle. Cannon thought the toxic agent was acid, citing that Fletcher found that acid is produced in tissue injury in 1907. Experimental trauma produced acid but his later experimentation (30.5) showed the amount of acid was insufficient to be significant. The Special Committee (144.5) found experimentally that trauma of a limb caused decreased blood pressure and shock. There was a gain in weight in the extremity which they attributed to blood in the tissue but thought it less than the amount necessary to account for the drop in blood pressure. They proved it was not neurogenic for section of the cord did not prevent shock when the limb was traumatized. They said it was not due to fat embolism for there were no signs of fat in the lungs or central nervous system. They said it was not acapnia for shock developed when there was normal carbon dioxide present. They decided by exclusion that it therefore must be vascular. They blocked the venous return from a limb and trauma did not produce shock until the venous drainage was restored--when veins again were clamped the blood pressure rose and they concluded that the toxic substance was readily detoxified or excreted from the body.

In 1919 Turk (154) found that the consequences of cell necrosis affect the organism causing some symptoms of shock when injected intravenously.

In 1903 Vincent (158) found that watery extracts of tissue injected intravenously produced a decrease in blood pressure, and this was taken as supporting the toxic theory.

The Special Committee (144.5) elaborated the theory of a toxic factor due to tissue injury causing shock. They thought a toxic factor, perhaps histamine, combined with loss of plasma or blood, caused a reduction in the circulating volume, which impaired the filling of the heart and its output, and that this was the cause of the progressive lowering of arterial pressure and eventual death through asphyxia. The action of the toxin was directly on the capillaries causing dilatation, increased permeability and escape of plasma, thus causing concentration of the blood.

Quenu (31), a Frenchman who studied shock during the first war gave these reasons in support of the toxic theory: (1) secondary shock is not immediately after wounding and therefore is not nervous--it is also too soon for infection, (2) secondary shock is seen with extensive wounds especially and the non protein nitrogen is elevated, which he considered due to absorption of injured tissue, (3) there is more shock where there is better absorption, (4) anything slowing absorption delays shock--remove the delay and precipitate shock; e.g. remove a tourniquet, and (5) suppression of the injured area, if not too late, causes shock to disappear, e.g. quick amputation often prevents shock.

In 1921 Cannon (30) said the effects produced by injection of histamine were so similar to the shock picture that the existence of

a toxic agent has a very high degree of probability.

In 1923 McIver (117) said there was some evidence of a toxic factor. If there were a toxic factor present one should be able to produce shock in secondary animals by crossed circulation--there have been numerous reports on both sides of this experiment and one cannot say whether shock occurs in the second animal or not.

In 1927 Randall (135) supported the toxic theory by stating that when the tourniquet was removed from a crushed extremity shock usually occurred one half to one hour later.

In 1927 Phemister (129) said there was no toxic agent and the fluid loss in the traumatized area was more than that which must be withdrawn to produce shock experimentally.

In 1930 Blalock (15) discredited the toxic theory by stating that the increased oxygen content of blood from traumatized areas which he found suggested a local accumulation of blood at the site of trauma and therefore there was no general bodily effect which would be produced by a substance like histamine.

In 1935 Slome (144) said the toxemia theory was incorrect because (1) the quantity of depressor substance in the traumatized muscle is inadequate to produce shock, (2) occlusion of venous return from a traumatized limb does not prevent shock, (3) there is no evidence of a toxic substance in the area of trauma or in general circulation in the shocked state, and (4) histamine poisoning produces different changes. O'Shaughnessy (128) in 1935 concluded there was no histamine or any other depressor substance present

which played a role in shock production. In 1936 Moon (121), although he did not agree with the toxemia theory, said that if there were a toxin in the blood it need not be in an effective concentration in the blood at any one time, for shock developed over a long time after a long continuous effect. Davis (46), in 1939, said the distribution of blood in histamine poisoning was different from that of shock and therefore shock was not due to histamine. In 1942 Wiggers (163) said that while histamine has not been finally excluded as the toxic agent, it is the concensus of opinion that it is not the agent concerned. If a toxic factor exists it is far more probable that a variety of agents rather than a common one is concerned.

Traumatic Metabolites Giving Capillary Atony and Tissue Anoxia

Moon's theory (123) is that there is a toxic substance produced by traumatized tissue metabolism which acts locally directly on capillaries. He said traumatic toxemia was not the cause for injury to muscle alone does not cause shock until several hours later, and histamine produced a different pathological picture. He said there was a toxic factor, arising from damaged and dying tissue and operating to cause a local increased permeability of the capillary walls and a consequent reduction of blood volume by escape of plasma into the lymph spaces, but there was no evidence of histamine or any such factor. Hemoconcentration resulted and the vicious cycle was instigated--local fluid loss and the discharge of nociceptive nerve stimuli were considered the instigating factors and the

vicious cycle the maintainin mechanism.

Local Fluid Loss Theory

The theory that local fluid loss was the cause of decreased blood pressure and shock developed following that instigating mechanism was first suggested by Phemister (129). Trying to find the cause of decreased blood volume through the study of toxemia, Phemister found that the blood and fluid loss in the traumatized area is more than must be withdrawn to produce shock experimentally, and concluded that it was the cause of shock.

In 1930 Blalock (15) again reported that he could find no evidence of a toxic factor and said the loss of blood volume into the traumatized area was sufficient to account for the reduction in blood pressure and that there was a loss of more plasma than cells, thus accounting for the hemoconcentration.

In 1935 O'Shaughnessy (128) said local fluid loss and discharge of nociceptive nervous stimuli were the etiologic agents.

In 1939 Davis (46) stated that in traumatic shock there was established a point of excessive permeability of the vessels and splanchnic vasoconstriction forced more blood into the area and out into the tissue.

In 1941 Dunphy (54) considered the fluid loss at the site of injury the initiating factor in reduction of blood volume and hemoconcentration.

In conclusion we say, the theory of local fluid loss has neither been proved nor disproved--it remains another unsolved problem.

Progressive Oligemic Anoxia

Harkins theory (81) of progressive oligemic anoxia is very completely described in his definition which has been quoted. It is really just a modification of the local fluid loss theory for he considers that the primary cause of oligemia upon which all the other changes are based.

Potassium

Harkin's classification does not include the potassium changes for there has actually been no theory that potassium changes are the initial cause of shock, although many have noted changes of location and concentration.

Scudder (140) in 1940, summarized the literature on potassium. He wrote that the factors which cause either a momentary or sustained rise in blood potassium are many. However, the efficiency of the kidneys in excreting this base, the action of the liver in holding back potassium and its excretion into the bile, the temporary storage in the muscles and red cells together with the loss which occurs through vomiting and salivation illustrate a few of the factors which keep its level in the blood within physiologic proportions. Should this fail to occur and potassium accumulate in the body fluids, its toxic manifestations become apparent. Small amounts of potassium stimulate and larger amounts depress the systems. Poisoning is shown in vasoconstriction of the vessels and tetanic contraction of the heart. Small amounts cause a rise in blood pressure and larger amounts cause a fall. The action of adrenalin has been

attributed to the increase in blood potassium. Scudder applies this information to shock and concludes that it is evident that one of the variables in the phenomenon of shock, whether produced by tissue abuse, loss of fluids, hemorrhage, stimulation of the sympathetic nervous system, injections of toxins, or destruction of the adrenal cortex, is an alteration in potassium metabolism, a derangement which serves as an indication of profound cell injury.

In 1938 Zwemer and Scudder (167) studied shock and found increased potassium much the same as in adrenal insufficiency. They concluded that since excess potassium in extracellular body fluids in shock is in many respects similar to that of histamine poisoning, and as injections of histamine are followed by increased blood potassium, shock may be due to a histamine-like substance. They thought potassium regulation may be a function of the adrenal cortex. They said, "The remarkable constant regulation of potassium by the body is altered during the condition of shock. Fluctuations suggest alternate success and failure in regulation, and a sudden increase produces death." In explaining the process they said, "Since a marked increase in extracellular potassium is injurious to cells, and injured cells lose potassium, a vicious cycle ending in death may be initiated if the plasma potassium is allowed to rise." They said the therapy which helped the body restore and regulate potassium is sodium salt therapy, adequate but not excess fluid, and cortin therapy.

There have been articles stating there is increased potassium

and others stating there is decreased potassium. In 1938 Bisgard, McIntyre and Osherhoff (11) found that in traumatic shock there was no consistent alteration of sodium, potassium, or chlorides.

In 1941 Harkins (81) said that hyperpotassemia might result from general cell injury and become involved in the cycle.

Wiggers (163), in 1942, concluded that while hyperkalemia has not been proved to be a factor which precipitates circulatory failure, this important complication of shock deserves further study.

The Clinical Picture of Shock

Early in the history of the condition there were observations made but there were none very complete until the oft quoted one made by Fischer in 1770, who reported a case describing the picture so well that none better has been made (160). Translated it is:

"The patient, a strong and perfectly healthy young man, was struck in the abdomen by the pole of a carriage drawn by runaway horses. We have not been able, after careful examination, to find any trace of injury to any of the internal organs. Nevertheless, the grave symptoms and the alarming look which he still presents made their appearance immediately after the accident. He lies perfectly quiet and pays no attention whatever to events about him. The pupils are dilated and react slowly to light. He stares purposelessly and apathetically straight before him. His skin and such parts of the mucous membranes as are visible are as pale as marble, and his hands and lips have a bluish tinge. Large drops of sweat hang on his forehead and eyebrows, his whole body feels cold to the hand, and a thermometer indicates a degree and a half Centigrade in the axilla and a degree in the rectum, below normal. Sensibility is much blunted over the whole body, and only when a very painful impression is made on the patient, does he fretfully pull a wry face and make a languid defensive movement. If the limbs are lifted and then let go, they immediately fall as if dead. The urine is scanty, dense, but free from any traces of sugar and albumin. The pulse is almost imperceptible and very rapid. The arteries are small and the tension very low. The patient is conscious, but replies slowly

and only when repeatedly and importunately questioned. On being thus questioned, he complains of cold, faintness, and deadness of the extremities. His respiration is characterized by long, deep, sighing inspirations, alternating with very superficial ones, which are scarcely audible. While being brought to the hospital he vomited several times, and nausea and hiccoughs still remain. His pallor, cold skin and hoarse voice immediately recall the appearance of a cholera patient; characteristic dejections are alone wanting to make the resemblance complete."

Diagnosis of Shock

The clinical picture described is an advanced case of shock and is easily diagnosed. It is important to diagnose the condition when it first begins to develop, for therapy is ineffective once the condition is definitely developed and the **vicious** cycle is established. Early diagnosis during post-operative shock is made more difficult by the anesthesia which covers up part of the early signs such as motor and sensory depression, sweating, palor, and changes in facial expression. In the early states there is nothing much upon which a diagnosis can be made. Blood pressure readings were first the method of diagnosing shock but we not believe that blood pressure decrease is a later development. Hemoconcentration is the first sign according to Moon (123) but it is not always diagnostic early for not all patients with hemoconcentration develop shock. Scudder said decreased blood volume is the first sign (140) but the same is true of this. Decreased venous pressure is considered by some to be the first sign but it is not always diagnostic.

During the progressive stage Wiggers (163), in 1942, said that the best criterion is a progressive decline in central venous pressures, in cardiac output, and in arterial pressures. Hemocon-

centration is of value diagnostically only when found in conjunction with these.

The autopsy reports have been so variable that one cannot diagnose shock merely from the pathologic findings as post-mortum examination.

For practical diagnosis at the present, progressive fall of blood pressure and pulse pressure is the best sign. There have been various pressures considered the definite line between shock and non-shock but it is not possible to state just what pressure indicates shock is present. A progressive fall is the criterion for diagnosis and indication for the instigation of therapy.

Relation of Shock to Hemorrhage

As soon as shock began to be considered as a disturbance in circulation it began to be considered as the same thing as ~~hemorrhage~~. In 1970 Clark (31) said shock and hemorrhage were the same thing. In 1876 Blum (140) said "shock is hemorrhage and hemorrhage is shock." In 1891 Lane (103) reported treating a case of "shock due to post-operative hemorrhage" with intravenous saline, thus implying he thought hemorrhage was one of the causes of shock. In 1919 Erlanger (60) said that shock developed from injuries which were almost always accompanied by more or less hemorrhage. In 1924 Gatch (75) found that a much larger amount of blood was lost in sponges etc. during operations than was commonly thought. He considered this blood loss to be very important in the development of post-operative shock.

In 1936 Moon (122) thought shock and hemorrhage were distinct entities. He said that those who have confused shock with hemorrhage have been correct in the belief that the mechanism of death is identical in both conditions. Their error lay in the assumption that, because hemorrhage will produce shock, all shock is produced by hemorrhage. Moon (123) said the circulatory deficiency of shock and hemorrhage results from an uncompensated disparity between the volume of blood and the volume capacity of the vascular system. He differentiated them by saying, "When this syndrome results from hemorrhage the blood will show dilution and when resulting from dilatation and permeability of the capillaries, hemoconcentration will be present." He also said there were pathological differences.

Coonse (33) also was very confirmed that shock and hemorrhage were different. They stated that traumatic shock is accompanied by acidosis and increased blood concentration, while hemorrhagic shock is not. Since acidosis is secondary of course acidosis does not result immediately after hemorrhage if the loss is great, but it develops later. It is more marked after slow hemorrhage and later Coonse said that in slow hemorrhage the findings were nearly resemble those of traumatic shock. In 1934 Blalock said the time factor had not been adequately considered (16), and that traumatic and hemorrhagic shock were the same thing, for when, after hemorrhage not immediately fatal, the blood pressure remained low for several hours, there was loss of fluid and hemoconcentration just as in shock.

Freeman (72), in 1935, compared hemorrhage and shock, and said that if enough time were given, hemorrhage would present the same findings as shock. In 1937 Davis (44) studied shock and hemorrhage and stated that the histopathologic appearance is the same in both, which suggested that the basic etiology is similar.

Concluding we find that the weight of evidence is that shock and hemorrhage are due to the same process after the initial loss of blood has begun the process. Results are the same, therefore hemorrhagic and traumatic shock are the same clinical entity.

Relation of Post-operative Shock to Other Types

The condition of shock was found to follow trauma and nervous excitement long before it was described as occurring post-operatively. The first reference to shock occurring after operations was made by Abernethy (31), who, in 1804, commented on a patient who "sank in shock in consequence of the operation."

At first the various types of shock were studied separately and gradually it was noted that they were much the same clinically although produced in different manners, i.e. by different instigating factors.

Fischer (160), in 1870, noticed the similarity of appearance of patients with traumatic shock and patients with cholera.

Meltzer (118), in 1908, stated, "Surgical shock differs from traumatic only in slower development. Possibly the pathologic state preceeding the operation, the anesthesia, and the loss of blood combine to obscure the sharp outlines of shock as seen in

purely traumatic cases."

Erlanger (59), in 1918, said, "Shock supervenes in consequence of extensive tissue damage not necessarily traumatic in origin."

In 1919 Cowell (35) said, "The bulk of the cases of surgical shock correspond to the common variety of wound shock," and thought secondary shock was mainly preventable especially that occurring post-operatively.

In 1921 Crile (38) concluded that the conditions were identical caused by surgery, trauma, toxins, anaphylaxis, drugs, exhaustion, starvation, hemorrhage, cold, inhalation anesthetics, etc. The basis for this opinion was that the cytologic changes were the same and that, however caused, they were due to secondary anemia causing asphyxia and intracellular acidosis which interfered with intracellular respiration--"life itself."

In 1930 Atchley (3) stated, "Medical shock is a condition which is the same as surgical shock only it is reached differently..the treatment is more or less independent of its cause. Whether it is due to trauma, toxemia, hemorrhage, or anhydremia, the physiologic problem is the same; namely a disproportion between blood volume and vascular bed."

In 1933 Moon (120) observed that the circulatory changes and degree of hemoconcentration due to trauma, burns, metabolic toxins, certain drug poisonings, intestinal obstruction, pancreatitis, perforated ulcer, and severe infections were the same and considered them due to the same mechanism. In 1936 (122) he found the mechanism

of death following intestinal obstruction and traumatic shock to be the same--the pathology and physiologic disturbances were the same.

In 1941 Davis (49) studied "dehydration shock" produced by burns, trauma, plasmapheresis, and dehydration, considering the process similar.

In summarizing the literature one finds the concensus of opinion is that shock is a symptom complex which is caused by many different initiating factors, but upon which, secondarily, the same physiologic process--the "viscious cycle"--is superimposed. Thus the same clinical picture--shock--is the final result. Therapy is therefore the same, and is based upon preventing the establishment and development of this process, the "viscious cycle."

Classification of Shock

At first shock was classified according to the originating condition, i.e. surgery, trauma, burn, etc. Many, including Moon, (123) used this classification. Since we have known that the shock is the same regardless of the instigating mechanism, that classification is not very good.

The classification made by Blalock in 1934 (16) and presented again in 1940 (1940) is more acceptable. It is in regard to the primary mechanism rather than the instigating factor. The types are hematogenic, neurogenic, and vasogenic.

Hematogenic examples are shock due to trauma, burns, rapid severe dehydration, and is secondary shock. This is the type being discussed in this paper and in the strictest sense is the only one

to which the term "shock" applies. The essential feature is the oligemia as the initiating factor with the blood pressure falling secondarily. Decreased blood volume causes vasoconstriction, hemoconcentration, stagnant anoxia, capillary dilatation, increased permeability, fluid loss and so the vicious circle..

Neurogenic is primary shock or syncope. There is decreased blood pressure although the blood volume may be normal. The onset is rapid. Influences acting on the nervous system cause vasodilatation due to decreased constrictor tone. Examples are spinal anesthesia, trauma, i.e. a reflex to a blow on the abdomen or exploration of the peritoneal cavity, psychic, postural, and carotid sinus syncope.

Vasogenic shock is due to vascular dilatation caused by agents acting directly on the vessels. Examples are histamine, nitrites, anaphylactic shock, and Addison's disease.

Perforated ulcer, e.g., first is followed by vasodilatation due to the neurogenic reflex. From this recovery follows, but soon there is vasodilatation due to vasogenic influences. This causes decreased effective blood volume, decreased blood pressure, decreased cardiac output, and anoxia. Then increased permeability, loss of plasma, hemoconcentration, increased viscosity, slowed circulation, and so the hematogenic process, occurs.

In his early classification he has a fourth type, the cardiogenic type which he says is undoubtedly rare. In this central type, in contradistinction to the other three which are peripheral circulatory failure, the veins are distended.

The Nature of Shock

In 1908 Porter (31) said of shock, "The symptoms of shock are a clinical entity about which there can be little dispute; shock, on the contrary, is a pathological state, the data of which are at present hypothetical." This statement is still so true that it might have been made yesterday. As has been stated, practically every one who has studied shock, and certainly everyone who has done experimental work on shock, has advanced a theory as to the etiology and process of the condition. The theories have been discussed.

As more and more facts were brought to light through the study of shock, it became apparent that many of the conditions found must be secondary to the primary initiating factors. In 1908 Meltzer (118) ventured the idea that there was a primary mechanism and later secondary effects occurred. The observations that all types of shock eventually had the same pathologic picture and physiologic process regardless of the initiating mechanism, showed many of the processes to be secondary.

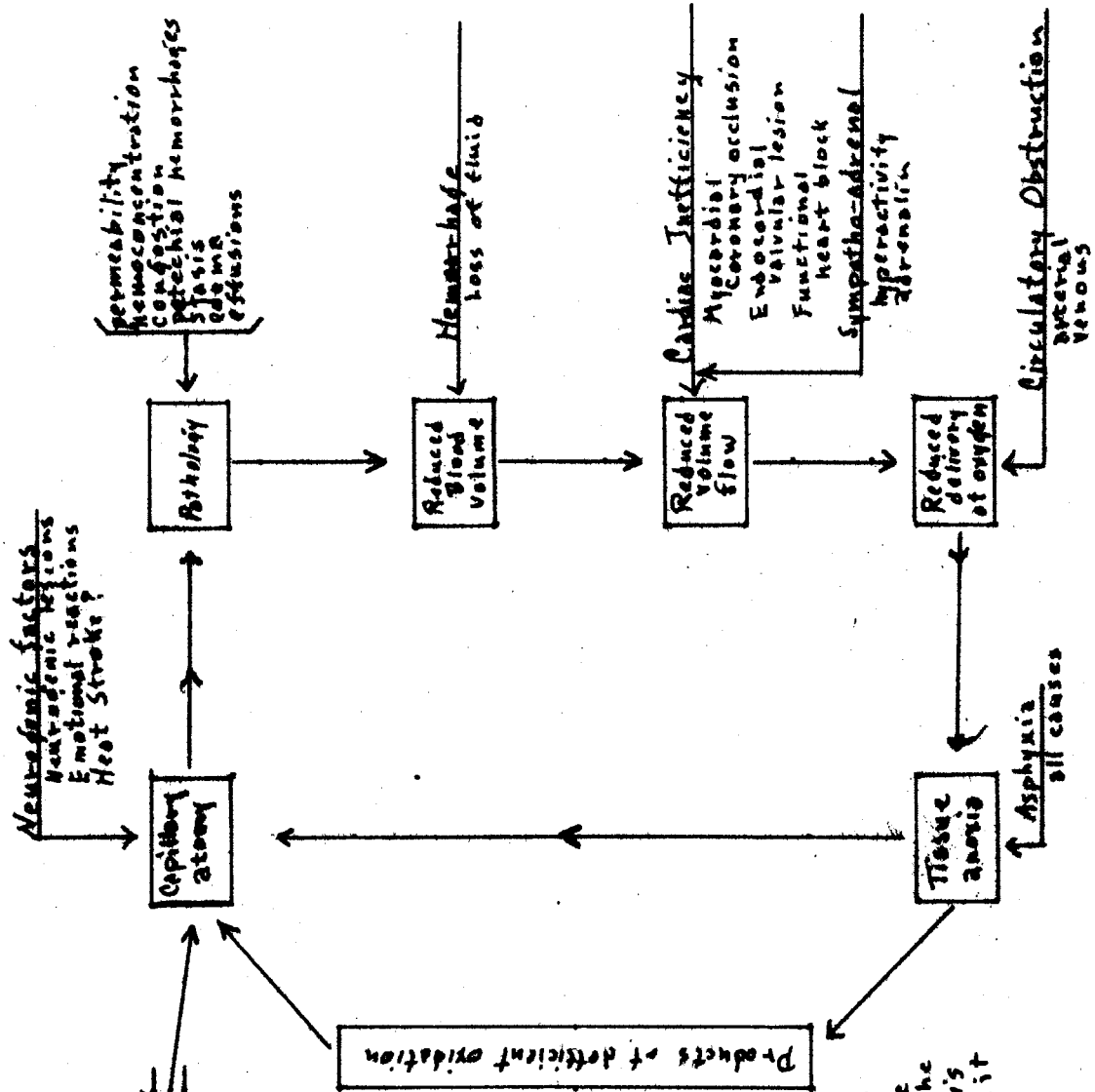
Erlanger (59) first used the terminology, "vicious cycle" in reference to the development of an interlocking chain of processes which developed secondarily and terminated in shock.

Cannon (31) in 1921, differentiated between initiating and sustaining factors. In regard to the etiology of traumatic shock he thought that toxic agents were most likely the initiating cause but were not working alone, there usually being some loss of blood, cold, exposure, run-down general condition, prolonged lack of food

and water, sweating, and anesthesia also present. He considered there were many sustaining factors. Decreased blood pressure due to decreased circulating volume caused decreased basal metabolic rate. Less heat production causes temperature drop. Decreased circulation causes decreased oxygen content of the blood. The nervous tissue is most effected by the anoxemia and the blood pressure is decreased more. Increased viscosity of the blood due to concentration and decreased temperature further decreases circulation. The vicious circle as explained by him is: (1) decreased circulation in capillaries causes less heat production and increased viscosity, (2) hemoconcentration causes less circulation due to increased resistance, (3) small veins and capillaries contain blood accumulation and plasma passes out into perivascular spaces, (4) more blood stagnates and there is less venous return, (5) blood pressure decrease causes loss of the "head" in arteries and the circulation decreases causing further stasis, and (6) the blood contains less oxygen causing capillary damage and more dilatation and less venous return.

In 1936 Moon (123) emphasized the vicious cycle (diagram on the next page) and made a rather extensive diagram of the factors involved. Moon demonstrated that temporary deprivation of oxygen causes capillaries to become atonic and permeable to plasma. Based mainly upon this fact are the elaborations of the vicious cycle.

In 1940 Henderson (95) thought the process was as follows:
Apart from hemorrhage, the initiating factors are intense pain, toxins,



- Agents of Conditions
Extrinsic to Capillaries
- Trauma
 - Burns
 - Extensive Surgery
 - Intoxications
 - drugs
 - metabolic
 - bacterial
 - Sexual disease
 - Abdominal obstructions
 - perforations
 - peritonitis
 - Pancreatitis

Moon - 123
The vicious cycle
and associated factors

One errs that Moon thought the instigation of the cycle was factors injurious to the capillary wall. The cycle is the same no matter where it is started.

anesthesia, etc., which he thought tended to depress the motor nerve cells in the spinal cord. To quote him, "the extreme muscular weakness which results involves also such a loss of tonus and pressure in the skeletal and visceral musculature that the blood stagnates in the tissue capillaries. Consequently, the venous return and cardiac output are diminished until the utmost effort of the vasomotor mechanism can no longer maintain arterial pressure, and it falls. Coincident with the loss of muscle tonus, metabolism and heat production are so much decreased that body temperature falls. The production of carbon dioxide is so much decreased that acapnia, acarbia, and depression of the respiration follow. With the decrease of the circulation, the arteriovenous oxygen difference increases until the venous blood is almost anoxic. In the asphyxiated tissues, the capillaries become permeable; the volume of blood decreases, while its concentration increases. If a saline solution is injected, it promptly leaks out into the tissues. The condition becomes a form of asphyxia."

In 1941 Riley (137) concluded that an understanding of the pathogenesis of shock requires a knowledge and recognition of the normal capillary circulation. His concept of this is, "In normal tissue the capillaries go through cycles of patency and non-patency which are regulated by the Rouget cells or by the capillary endothelium itself. This cycle is governed by the depletion of oxygen and the production of metabolites which, working together, cause the capillary to open to the circulation. With the flow of blood

through the capillary the metabolites are carried away and oxygen is supplied to the tissues. Also, in this new blood supply there is a substance, apparently from the pituitary, that causes the capillary to contract and occlude itself. In normal tissue this cycle goes on, governed by the activity of the tissue supplied by the capillary. In incipient shock, regardless of the underlying causative factor, this normal cycle is interfered with. The result is the establishment of a vicious cycle of tissue anoxia, capillary atony, decreased venous return, decreased cardiac output, decreased oxygen supply to the tissues and so back to tissue anoxia."

In 1941 Harkins (81) said, "With all of the changes going on, it is often difficult to tell which are initiating, accompanying, or perpetuating factors...In different clinical conditions the proportionate importance of different causative factors may vary and in some more than one cause may be active." He said fluid loss is the initiating factor in hemorrhagic shock and the other changes act in accompanying or perpetuating the condition. In burn shock, for example, the fluid loss is plasma, and in traumatic shock it is whole blood and plasma. He thought that a large fluid loss might be the only factor of etiology but if the loss were not so large, however lasted longer, there probably were additional causative factors involved. In explaining the mechanism he said, "The primary result of the fluid loss is an oligemia with associated vasoconstriction, decreased cardiac output, and decreased blood flow. This latter factor is important in producing an anoxia and

resultant general capillary wall and cell injury. A progressive hemoconcentration usually results from the general capillary wall injury."

Wiggers (163) thought the key was progressive circulatory failure which he considered of basic importance from etiologic, prognostic, and therapeutic standpoints. He said that there was not only an initiating process, and a sustaining process, but also a precipitatory mechanism. To quote him, "While venous return is reduced relatively early in shock and represents the chief factor in its continuance, such a decrease alone does not suffice to create the irreversible circulatory failure characteristic of deep shock. Consequently, the suggestion is ventured that some as yet unidentified precipitatory mechanism or several of these in association exists."

As with any infectious disease, death may be prevented when an initiating factor is present if secondary developments are prevented. The two ideas considered today as initiating factors are decreased circulation due to decreased blood volume by hemorrhage or local loss of plasma, and decreased circulating volume by stagnation of blood in capillaries. Decreased blood volume is important in hemorrhage and the severe dehydration caused by protracted vomiting, prolonged diarrhea, excess loss of gastro-intestinal secretions or their loss by drainage, loss of serum from wounds or burns, formation of large inflammatory exudates, etc. If the decrease is large it may cause death by respiratory failure, but if it is not so large it is

compensated a while until gradually produced asphyxia establishes the vicious cycle. According to this view capillary stasis and generalized plasma loss are secondary.

Experiments suggest that vasoconstriction may exist in certain territories of the body during shock, but there is no substantial evidence that it is sufficiently generalized or intense enough to cause the capillary damage which the vasoconstriction hypothesis requires. (Wiggers-163)

The amount of fluid loss has not been accurately enough determined to know whether the decreased circulatory volume is actual or relative. This statement is based on the diversity of opinion concerning the matter.

Histamine has not been definitely eliminated as the initiating toxic agent but the popularity of this belief is on the wane. If a toxic factor is present it is probably a variety. It may require an activating agent and Wiggers suggests (163) that possible participation of an endocrine factor would explain the development of a similar state of shock during cortico-adrenalin insufficiency.

There is no definite evidence that a failure of the venopressor mechanism could exist and cause shock.

Wiggers (163) stated that none of these theories have been proved and the instigating mechanism is unknown except in hemorrhage and plasma loss by trauma, burns, etc. where it is definitely known that the circulating volume is decreased by fluid loss.

Sustaining factors are generally accepted as the vicious cycle,

the time factor with ischemia and irretrievable capillary damage. Most believe that the ischemia progresses and that capillary damage soon results which cannot be improved by any therapy and then the condition results in death soon. Some explain the sudden death as a final failure of compensatory mechanisms. Wiggers (163) believes there is an additional precipitatory factor which finally causes death. He says, "It is hazardous to infer that capillary damage is the sole factor responsible for failure of response to blood or plasma transfusions." He suggests six factors which may be the precipitating factor and admits that none of them have been proved. They are: (1) cortico-adrenal influences, (2) translocation of potassium, (3) reduction of blood volume to a critical minimum, (4) default of the compensatory or emergency mechanism, (5) vasomotor failure, (6) myocardial failure, and (7) aortic adaptation.

The cortico-adrenal factor has been discussed.

Translocation of potassium has been discussed. It has not been proved but it is known that changes are present, and deserves further study.

Reduction of the blood volume to a critical minimum is an idea based on the fact that transfusions are ineffective late in the process. It is not the precipitatory factor but is probably indirectly responsible for it.

That there might be a default of compensatory or emergency mechanisms was thought by Rein and Wiggers thinks it could be present.

Rein lists four mechanisms which he thought might fail and precipitate shock. They are: (1) local chemical agents and axon reflexes which contrroll vessels by causing contraction and relaxation, (2) extrinsic reflexes from surrounding tissues or special organs such as the kidney, (3) intrinsic vascular reflexes through the sinus and aortic nerves which help maintain heart adjustment and adequate aortic pressure so local mechanisms can operate, and (4) collateral reflexes which exempt regions that require better blood flow from participation in the emergency reactions. He suggested that these mechanisms might be disrupted by afferent nerve impulses upsetting these delicate nervous relationships, or they might be disrupted by decreased pressure causing less effective blood reflexes.

Wiggers (163) suggested that, despite the weight of opinion that the vasomotor center was not involved, there might be some involvement late. His experimental evidence was that after low blood pressure had been maintained for hours and the vagus was stimulated, there was tremendous pressor effects in some dogs and no response in others. Ephinephrine caused a response in all, and so he concluded that the vasomotor center possibly was exhausted in those which gave no response.

Despite the statement that the heart was not involved in the etiology of shock, which has been almost universally accepted since the condition was first studied, Wiggers (163) says that possibly it might be the precipitating mechanism. The evidence he offers for thi opinion is, (1) in some dogs the venous pressure tends to

rise again suggesting passive congestion, (2) the heart slows after hemorrhage or shock progresses, (3) infusion of blood or plasma may increase the venous pressure and still there be no increase in blood pressure, and (4) artificial respiration may be continued and then death occurs by progressive heart failure. Wiggers concludes that myocardial failure may possibly precipitate shock and certainly it is depressed in some cases.

In his experiments Wiggers found that after passive hypertension the aorta progressively decreased in size. He concluded that possibly the mechanism which adapts the size and elasticity of vessels to volume has failed. He concluded that (163) possibly this might precipitate shock.

In conclusion we see that the actual process is not agreed upon, but there is considerable information known about it, and all agree that there is the establishment of the vicious cycle, and that therapy, after its definite instigation, is not very effective if at all.

Clinical Application of the Knowledge--Prophylaxis

Early in the study of shock the only treatment was therapy of an already existing condition. Later it was found that prevention was much more effective than therapy.

In 1881 Jordan (140) thought that anesthesia diminished the possibility of shock.

In 1895 Warren (160) said factors to be avoided in operations were prolonged exposure, and unnecessary handling of the intestines.

He also said to avoid blood.loss.

In 1897 Turck (153) noted the benefit of warmth and ran warm water into the stomach through a double tube during the operation to prevent shock.

In 1897 Crile (36) found the duration of operation to be an important factor in shock production and suggest rapid surgery. He considered exposure of the tissue, both in duration and area, was important. He noted that cold was a contributing factor and advocated keeping the patient warm. He found that the physical condition of the patient pre-operatively was important and that the patient should be prepared as much as possible pre-operatively. He said that the anesthesia might be a factor and that chloroform was more toxic than ether. He found that hemorrhage predisposed to shock but considered it merely one factor in the production of shock. He considered shock due to nerve stimulation and said that when the nerve-trunks had been blocked by cocaine that shock did not appear. He suggested careful handling of the intestines and keeping them covered by the omentum, avoiding all unnecessary manipulation. They found the most dangerous area of operation was in the region of the duodenum, pylorus, and gall-bladder but considered that preliminary injection of cocaine would almost wholly prevent such effects. He noted that prevention was much more effective than treatment. Although Crile's theory of the cause of shock is no longer accepted he originated methods of prophylaxis which have been very effective regardless what the instigating

mechanism is. Although surgeons no longer believe it necessary to use local anesthesia on every plane before incision, the rest of his ideas have been used ever since.

In 1915 Johnson (123) listed a number of exciting causes which should be avoided by the surgeon, among them being inadequate preparation of the patient physically and nervously for the operation, excessive blood letting, and excessive surgical trauma. He said too light anesthesia, chilling, and any condition causing strain on the mechanism of respiration were conditions to be avoided by the anesthetist.

The Special Committee (144.5) reported several factors which should be prevented to help prevent shock, among them excitement, cold, thirst, fatigue, and possibly loss of sleep. They said that with so many factors involved in producing shock, the elimination of one of them, e.g. cold, was very important and had proved quite effective in cutting down the number of shock cases.

In 1919 Cowell (35) said that pre-operative factors contributing to surgical shock, were undue anxiety, chilling, pre-existing bacterial toxemia, and hemorrhage, and factors during the operation were heat loss, anesthesia, hemorrhage, and trauma. He suggested eliminating all these as much as possible.

In 1921 Crile (38) presented his shockless operative technique of "anoci-association" which was based on his studies starting in 1897. This operative process was to use an operative technique which minimizes shock producing factors, using nitrous oxide anesthesia,

lessening trauma, and anesthetizing each layer by local injection of novocaine before cutting it.

In 1922 Cannon (30.5) suggested morphine in helping to prevent the formation of the vicious circle, his reason being that it lessened the tissue demand for oxygen.

Moon (123), in 1936, stated that it was standard practice in many surgical clinics to employ preventive measures before, during, and following operations, and so it is in all today. Traumatization of tissues is avoided so far as possible. The cutting instruments are keenly sharpened because a dull knife injures the tissues far more than a sharp one. The application of clamps and hemostats is reduced to a minimum, for the aggregate amount of tissues so crushed may be considerable, and ligatures are applied the same way. Necrotic tissue increases the effects of absorption from the wound. The viscera are manipulated gently, and unnecessary sponging of serous surfaces with gauze is avoided. Prevention of hemorrhage is stressed. The duration of the operation is made as short as is consistent with careful technique.

Boothby (21), in 1940 said the prophylactic methods used at the Mayo Clinic are (1) careful but rapid surgical technique, (2) heat externally and internally by warm gastric and colonic irrigations, (3) control of fear and pain pre-operatively by morphine, (4) pre-operative correction of dehydration, (5) correction of secondary anemia pre-operatively in selective surgical cases, and (6) oxygen inhalation, 100%.

Riley (137), in 1941, reported the method used by the Lahey Clinic. They always give continuous intravenous saline in gastrointestinal surgery. If at any time during the operation it becomes apparent that shock is oncoming, measures are taken immediately to prevent its establishment--the patient is given a mixture of 2mg. of ephedrine and 5 units of pitressin intramuscularly, blood is substituted for the normal salt solution, and oxygen inhalation is started. When spinal anesthesia is being used one of the anesthetic gases or pentothal sodium intravenously is started to conserve the patient's energy. Should these measures fail to halt the development of shock, the operation is limited, if advisable, and completed at a later second stage.

Post-operatively it is important to prevent dehydration and one must not forget that there is a large fluid loss during the operation by sweating, respiration, drainage, blood loss, etc. which must be replaced.

In conclusion we find that the prophylactic measures taken to prevent shock are universally much the same, and all instigate intravenous blood and blood substitutes at the first sign in order to prevent development of shock.

Treatment of Existent Shock

"Rest and quiet are advocated and are effective according to any of the theories, for they would prevent nociceptive stimuli, prevent squeezing toxins out of injured tissue, and prevent hemorrhage and fluid loss," says Wiggers. (163)

Elevation of the feet was first advocated by Hill (85), but later this was considered not good therapy for it was supposed to have interfered with the circulatory normal mechanism and also with respiration. It is used now by some, care being taken to prevent interference with respiration. Riley, however, says (137) it is no good and may be disturbing to the patient.

Warmth was first suggested by Turck (153) who used a double stomach tube to irrigate the stomach with warm solutions. The Special Committee (144.5) of War One was very much in favor of warmth and found that through this one measure alone they greatly cut down the occurrence of shock. Too rapid warmth has been warned against for it might cause dilatation of skin vessels and further decrease the effective circulatory volume.

Sedatives are used pre-operatively to cut down anxiety. Morphine was advocated by Cannon (30.5) who thought it would cut down the oxygen use of the body and lessen development of anoxia, but he warned that too much would exaggerate the condition of anoxia, and today it is not used too much for the latter reason.

Vasospastics have been suggested to be harmful rather than beneficial, for it is thought they might increase vasoconstriction and lessen the circulation to tissue already partially asphyxiated. Riley (137), in 1941, however, advocated the use of ephedrine and pituitrin intravenously in combatting oncoming shock followed by fluids. He used pituitrin intravenously in established shock and followed it by fluids.

Fluids are the main therapy used. They are used to attempt to get at the underlying pathology and they maintain circulation preventing tissue anoxia and establishment of the vicious cycle. Oral fluids have been suggested but they are only good in general prophylactic therapy and not effective in the shocked state. Proctoclysis has been used by some in prophylactic use, and Riley (137) advocates its use both for fluid and to help warm the body. It does not work very well therapeutically for it is not very rapidly absorbed. The temperature of injected fluids was formerly thought to be necessarily warmed, but recent evidence offered by DeGowin (50) is that it is safer not to prewarm blood and any parenteral fluids may be given just as safely at room temperature. Intra-arterial injections of fluid has been advocated but it is just in experimental stages.

Water, as has been stated, is important in preventing dehydration which is a factor in shock. MacFee (107), in 1934, used saline and noted a decreased incidence of shock. Many since have advocated the use of fluids prophylactically but it has been found of little benefit for treatment of the ~~ex~~istent condition.

Intravenous saline was first used in shock for it was thought transfusion of blood was dangerous. Later it was found that the fluid passed on out of the permeable capillaries and the effect was only temporary. Scudder (140), in 1940, expressed the belief that the sodium in saline solution relaxes smooth muscle of the constricted arterioles. Perhaps it is useful if used early.

Hypertonic solutions have been advised due to their osmotic action and greater viscosity but they are now considered dangerous because they may increase the blood volume at the expense of cell water (Wiggers--163). The increased viscosity also may be harmful, for with shock there is already increased viscosity which is a hindrance to circulation.

Glucose was advocated by Erlanger (58), in 1917, as a means of protecting the liver and as a source of energy.

Acacia was elaborated as therapy for shock by the Special Committee (144.5) and it was used very extensively during the first war. It was found to be very effective for it did not pass out through the permeable capillaries as did the saline solutions. Bayliss (7), in 1922, said at best it was only a blood substitute and advocated early transfusions. More recent evidence is that there is damage to the liver by acacia. Studdiford (146) found extensive destruction of the liver at autopsy of deaths following the intravenous use of gum acacia. He concluded that the only time acacia should be used is when, in shock and hemorrhage, it must be used as a last resort because blood is not available. In 1938 Hall (79) found that repeated intravenous injections of gum acacia in dogs results in evident damage for carbohydrate and serum protein metabolism functions of the liver. Others have also noted damage following acacia. Harkings (81), in 1941, said that while acacia might be of benefit, there are other more perfect blood substitutes, e.g. plasma.

Ascitic fluid has been tried experimentally and found to be effective. Davis and White (45) first tried this form of therapy experimentally in 1938. Since then it has been tried by other experimental workers but it has not been tried yet in man.

Blood transfusions were first suggested in 1750 by Heister, (140). They were later discarded for saline because it was thought transfusion was dangerous. In 1910 Crile (39) advocated the use of blood transfusion for the treatment of shock. It has been used since and many have written on its efficacy. Harkins (81) emphasizes the idea that transfusion of blood does not merely mean 500cc--one should regulate the amount according to the individual patient and give each patient what he needs, using several donors if necessary.

Stored blood originated in the blood bank system at Cook County Hospital in Chicago (64). Blood was found well stored by citration and sulfanilamide powder. DeGowin (50), in 1940, reported that plasma potassium increased considerably in stored blood, but that when given slowly such blood was not toxic after stored one month. He found that dextrose-citrate mixture was the best preservative solution. Many have found the addition of dextrose makes preservation more efficient.

Placental blood was tried in 1940 by Fine (66) but he found it to be impractical. The main trouble, he said, was a high per cent of contamination of the blood.

In 1940 Scudder (140) said that stored blood's best use would be in hemorrhage and shock, and there the improper use carried the

greatest risk. The disadvantages of stored blood, said Harkins (81) is deterioration, largely from diffusion of electrolytes such as potassium and magnesium, from the cells into the plasma. This is especially rapid when the blood is transported, which again limits its use.

Youdin started the use of cadaver blood in Moscow in 1938 (55). Blood is obtained from carefully chosen patients and it seems to be very good for therapy. The advantages according to Youdin are, (1) a large amount is obtained from a single donor, (2) it is free, (3) fibrinolysis occurs in patients with sudden death and therefore it is unnecessary to citrate it, (4) there are fewer reactions because there are no preserving fluids, (5) a wasserman can be done on the blood and be absolute, while in living man there may be syphilis anyway, and (6) necropsy guarantees the innocuousness of the blood, and the possibility of non-clinical disease processes is eliminated.

The importance of plasma loss in shock has been discussed. Plasma was suggested for shock therapy by Rous (139), in 1918, in reporting on fluid substitutes for transfusion. Since then it has grown in recognition and has been advocated by many. In 1938 an Editorial in the J.A.M.A. (56) said dissolved processed plasma was found to be very effective in treating traumatic and burn shock, especially the burn shock. In 1940 Brennan (23) presented the information that in shock the red blood cells were enlarged as much as 50%, probably by absorbing hypotonic tissue fluid taken into the

blood stream. He said that these enlarged cells became clogged in capillaries and stopped circulating, and that plasma injection was hypertonic and the excess fluid left the red cells and they became free and circulating again. In 1940 Crowley (41) originated a method of obtaining plasma in which the cells were saved also so they could be used where indicated. The main part is the use of a dumb-bell shaped tube in which the blood is run when citrated. The cells settle to the bottom part and plasma stays on the top upon centrifuging. The two ends are then broken apart and sealed, thus leaving a container of plasma and one of cells. Scudder (140) believed plasma to be less toxic than serum, but Best (10), in 1940, said that plasma and serum were therapeutically identical in shock treatment. The advantages offered by serum are, it can be given without typing, contains no particulate matter even after long storage at either room or icebox temperature, it requires no filter for administration, and it passes through a bacterial filter, insuring sterility. It can not, however, be made from bank blood unless it is made from plasma, which has been done. In 1940 Edwards (57) dried plasma by vacuum distillation and it is being used in this way by the British army. Since that time dried plasma has been advocated by many men. Riley (137), in 1941, said dried plasma diluted up to four times normal concentration was the best therapy for shock. Blalock (19), in 1941, said intravenous fluid is the most important single form of therapy and of these plasma and serum are the best. He lists the advantages over blood being, it can be stored for months

cold, it can be kept a number of days at room temperature, it is easier transported, no typing is necessary and there are no severe reactions, it is ready for instant use, and it does not add to the concentration of the red blood cells. In March 1942, Hill (82) advocated the use of dessicated plasma for prevention and treatment. The advantages of the dessicated form are that it can be prepared in four times normal concentration, can be made by mass production, and is easily prepared by freezing and dessicating by electricity. It preserves proteins without deterioration, it is rapidly soluble, it will not support bacterial growth, it is in reduced bulk, and there is no fibrin precipitation and no tendency for such after it is dissolved.

Oxygen has been used for some time due to the secondary anoxemia produced by failing circulation. Riley(137) said this form of therapy is only beneficial in the method that it quiets respiration and conserves the energy of the patient. Harkins (81) said that all patients in shock should receive oxygen. It is not beneficial in-so-far as the initial cause is concerned, but perhaps it helps in preventing anoxemia.

Adrenal Cortical Extract was suggested by Swingle and his co-workers who published a series of articles on this subject. (148, 149, 150, 151, 152) They thought the etiology of shock was adrenal cortex insufficiency and so advocated cortical extract for therapy. Freeman (71) said there was no basis for cortex extract since secondary shock and adrenal cortical insufficiency were not

the same clinical entity as had been claimed by Swingle. Zwemer (167) said that at autopsy in those who died of shock there was evidence of vacuolization of the adrenal cortex which suggested an inadequacy of hormone and that therefore adrenal cortical extract should be good therapy. Scudder (140) thought that adrenal cortex extract controlled the potassium of the body and therefore, since there was a change in potassium distribution and concentration in shock, it might be of benefit therapeutically. Besser (8) and others found no beneficial clinical results from the use of a prepared cortical extract. Wiggers (163) thought cortex insufficiency might be a precipitating factor and therefore that cortex extract might help therapeutically, but concluded that there was not enough known about it to definitely state. In conclusion we must say that there has not been enough evidence found in the literature to know the role of adrenal cortex insufficiency in the production of shock and in the shock syndrome, and so we do not know about the effectiveness of cortical extract therapeutically.

Conclusions

As a Conclusion nothing can be more appropriate than Porter's statement of 1908, "The symptoms of shock are a clinical entity about which there can be little dispute; shock, on the contrary, is a pathological state, the data of which are at present hypothetical."

The instigating mechanism is not known. That there is a vicious cycle established secondarily is generally acknowledged. This cycle is based on anoxemia and causes progression of the state.

Recently Wiggers has stated that probably a precipitating mechanism exists and stated several possibilities as to this factor.

Prophylactically most of shock occurring post-operatively is avoidable if proper precautions are taken. These include proper preparation of the patient for the operation as to general condition and prevention of unnecessary anxiety etc. Dehydration, anemia and other such conditions should be corrected pre-operatively. During the operation all precautions should be taken against trauma, length of operation, and blood loss. Should at any time the onset of shock become apparent, prophylactic therapy should be instigated at once in the form of transfusions of blood or plasma, and the operation should be terminated as soon as possible.

Treatment of shock is very efficient if started early. It has long been known that intravenous fluids were much more effective early, the basis for this finding being thought to be irreparable capillary damage due to anoxemia. The most efficient one form of therapy is intravenous fluids, e.g. blood and plasma or serum. Vasospastic drugs have been advocated by some but they should be followed immediately by fluids. Warmth has long been advocated but not excessive to the point of causing vasodilatation and lessening the effective circulatory volume of blood. Elevation of the feet is used by some but others say it does no good and only upsets the patient. Rest of the patient should be insured by sedation although not to the point of respiratory depression. Oxygen is beneficial in preventing anoxemia but is also only secondary to fluids. Adrenal

cortical hormone has been advocated by Swingle and his workers but this is just in experimental stages.

To Repeat--use proper precautions pre-operatively and during operations, and at the first sign of shock use intravenous plasma or serum, the amount to be adjusted by the need of the individual patient. As with most things, "An ounce of prevention is worth a pound of cure."

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