RESUSCITATION

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To resuscitate is to restore, re-animate or revive. Resuscitation has also been defined as the restoration of the apparently dead. In dealing with a subject of such wide implications it is necessary to make some selection, and in so doing I have chosen those aspects in which, for some years, I have had a particular interest, an interest which I hope to persuade you to share. I shall first recall some of the information we possess regarding the regulation of the composition and distribution of the body fluids and then apply this to the problems involved in the resuscitation of the injured and diseased, discussing the therapeutic fluids which are available and the circumstances in which they are most valuable.

Seventy-two years ago Claude Bernard, a member of this Society, wrote that, “It is the fixity of the internal environment which is the condition of free and independent life, all the vital mechanisms however varied they may be, have only one object, that of preserving constant the conditions of life and the internal environment.” This fluid environment is mainly controlled by the organism itself, and is now recognised to be part of the complicated interrelated physico-chemical equilibria which constitute modern man. These equilibria are the result of many evolutionary processes and are subject to neural and endocrine influences. Cannon put this more shortly when he said that “Regulation is the central problem of physiology.” This is true also of resuscitation, the attempt to regain control, which has been temporarily disturbed or lost, of the fluid environment on which life and normal bodily functions depend.

About 40 per cent. of the total body mass is composed of bone, tendons, skin and fascia, and 60 per cent. is made up of muscle and viscera (Harrison, Darrow and Yannet, 1936). It is a common belief that the supporting tissues are much less disturbed by metabolic changes than are the muscles and viscera. This may be an unwise premise, for Schoenheimer (1942) found that within three hours of the ingestion of labelled amino-acids, rats had transferred isotopic nitrogen to their bones. Such an observation does not imply any change in gross or even microscopic structure, but it does mean

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that the molecular composition of all tissues is being turned over constantly at a fast rate. If such a rapid interchange goes on in so-called fixed tissue, it is likely to be much more rapid in the body fluids.

According to Gamble (1947), 70 per cent. of the body by weight is water, distributed amongst three compartments or phases in quantities equal to 50 per cent. of the body weight in the cells, 15 per cent. of body weight in the interstitial fluid and 5 per cent. of body weight in the plasma. These distributions are shown in Fig. 1 and have been converted to actual volume equivalents for a 70 kg. or 10-stone man. The physical boundaries of the phases are the cell membrane and the capillary membrane.

At a given time only 6 per cent. of the total blood volume is in the capillaries, the remaining 94 per cent. being on its way to and from the capillaries (Learmonth, 1950). From the equilibration curve of heavy water in the human subject it has been calculated that about
73 per cent. of blood water may cross the capillary wall every minute (Flexner, Gellhorn and Merrell, 1942). By combining these statements, it appears that of the 7 litres of blood in a 70 kg. man, about 400 ml. may be in the capillaries at a given moment, and that, with a minute volume of 4 litres, about 1600 ml. of water may pass through the capillary walls each minute, that is to say a volume of over 2000 litres (nearly 500 gallons) may cross the capillary walls per day. This figure is not so surprising when we remember that Krogh estimated the area of the normal capillary bed at 6300 square metres (about 10 acres), and Landis expressed his estimate as a tract 3 feet wide and 4 miles in length.

These figures serve only to indicate the very fast potential rate of the turnover of body water. They give no idea of change in distribution of water between intravascular and extravascular or intracellular and extracellular phases. The movement of water into and out of these phases is controlled by the ions present in and characteristic of the phases, and by changes in distribution of these ions, the latter being dependent on intake and loss of the ions and changes in the boundary membranes of capillaries and of the cells. The so-called membranes, better considered as limiting zones of equilibration, are themselves subject to rapid and continuous differential changes of properties and so of permeabilities.

The chief intracellular cation is potassium and the chief extracellular cation is sodium, and with them are associated various acidic radicles. It used to be thought that the cell membrane was quite impermeable to sodium ions but readily permeable to potassium. It now seems more likely that both ions are able to pass across the boundary zone of the cells (Darrow, 1945), but that potassium normally does so more rapidly than sodium and that this, in combination with other factors, accounts for the usual higher concentration of potassium within the cells.

On the other hand, albumin is the factor largely responsible for the maintenance of a volume of fluid as plasma within the vascular system, because of the normal selective relative impermeability of peripheral capillary walls to albumin. However, it is now known that the capillaries of certain viscera, notably the liver, do not exert this restraint on the passage of albumin through their walls, and in the case of the liver it is probably well that they do not, for the portal venous pressure is often lower than the osmotic pressure exerted by the plasma albumin.

The red blood corpuscle is remarkable in that it is more closely confined within the vascular system than any of the other constituents of the blood, and it is this property which renders it such an important component of blood volume. The blood of vertebrates is the most complicated of all biological fluids, and is a remarkable example of adaptation to environment. In the maintenance of oxygen transport
at the mammalian level of specialised organisation there is no possible substitute for haemoglobin as the respiratory pigment. The mere presence of haemoglobin in an adequate concentration is, however, not enough, and there is much evidence that its peculiar situation, within the mammalian red cell, also confers special properties on the blood.

The gross water content of the body depends on a balance between intake and output. The kidneys do much to prevent unusual loss or accumulation of water in the body and respond rapidly and selectively to abnormal ingestion or loss of many substances in addition to water. In the normal subject there is a daily insensible loss of about 1000 ml. of water as vapour by respiration and diffusion through the skin and about 500 ml. is the minimum volume of water required for urine formation, making a total of at least 1500 ml. to be provided each day. When neither water nor food is taken, a small part of this 1500 ml. of water comes from the oxidation of fat and protein, but the rest is body water as such from the extravascular phase, and this continuing daily removal of body water is the factor which determines how long thirsting can continue. If water is supplied but food is withheld, some water is still produced by the oxidation of body tissues and from the extravascular fluid. Usually normal people consume water in excess of their minimum renal requirements as defined by the quantity of solutes which have to be excreted in the urine. Gamble (1948) has shown that in the fasting subject the provision of 100 gm. glucose per day will reduce protein catabolism due to starvation to the minimum of about 40 gm. protein (5-6 gm. nitrogen) per day. By reducing the quantity of solutes requiring excretion and so the minimum requirements for renal water, this sparing of protein conserves some body water. Ketosis also is completely prevented. In addition, this glucose reduces the urinary loss of sodium which occurs in fasting, but as a result there is, for some as yet unknown reason, an equivalent additional urinary loss of potassium.

When body fluids containing electrolyte are lost, replacement must be qualitative as well as quantitative, for only if it contains an appropriate cation can water remain in the body. Minimal water requirements also must be covered, otherwise the kidney will try to concentrate some of the administered base and so free water for urine formation. Even in the normal subject there is a difference in the response to the intravenous infusion of glucose solution and of saline. Five per cent. glucose solution produces a rapid and marked diuresis, the rate of excretion soon exceeds that of injection, and within an hour of the cessation of the infusion a volume of water has been excreted which is equivalent to that which has been injected. However, in the case of 0.9 per cent. saline the diuresis is less marked; only a small proportion (about 25 per cent.) of the infused fluid is excreted during the infusion, the remainder being slowly excreted during
the next twenty-four to forty-eight hours (Moyer, Levin and Klinge, 1947.)

From recent investigations it appears that immediately after injury and in inflammation there is a change in renal function which alters this regulatory effect. For a period of some days after the onset of inflammation due to injury or infection, there is retention in the body of water, chloride and sodium which is related in time to the production of the inflammatory exudate (Wilkinson et al., 1949). This exudate, composed largely of albumin, sodium, chloride and water, is derived initially from the blood circulating in the part and through the blood from normal tissues elsewhere in the body. Some change in capillary activity and permeability probably precedes the passage of this salty albuminous fluid into the intravascular phase. In the immediate post-operative period fluids administered by the intravenous route, especially if they contain sodium and chloride, may be more slowly excreted in the urine, with a consequent danger of excessive retention of these substances. Furthermore, qualitative and quantitative errors in the composition of such intravenous infusions are not so readily corrected by the renal differential excretion as in the normal and uninjured subject, and secondary disturbances are more likely to occur. In renal and cardiac disease this risk will be greatly enhanced. Immediately after operation the infusion of isotonic saline is followed by the prolonged retention of the equivalent of about half the sodium and chloride, but of only about one-fifth of the water. This leads to the transfer of water from the intracellular to the extracellular phase, a transfer which is made possible by the excretion of intracellular potassium. The size of the transfer can be reduced by the use of hypotonic solutions. During the period of retention, accumulation of fluid can be proved by measurements of body weight and urine output. The most likely site of this accumulation is where capillary permeability is most increased, namely, in the zone of inflammation.

So far I have tried to show that there is in the body a rapidly circulating fraction of the total fluid which we arbitrarily conceive as confined within the walls of a vascular system, and which serves as a vehicle for gaseous exchange and transport of materials; that in fact only part of this volume of fluid is so confined, the red blood cells and some of the protein, and that the remainder, some of the albumin and all the electrolytes and plasma water, pass freely to and fro across the capillary walls. We are, I think, compelled to conclude that of the fluids injected into the blood stream, only certain components can remain within the vascular system for long: red corpuscles, some plasma protein and foreign colloid substances such as gum acacia and dextran. The remainder becomes part of the fluid pool of the body and is largely beyond our control, being subject to physiological processes of which as yet we know little.
In resuscitation there may be two problems: first, the restoration and maintenance of blood volume and so of oxygen supply to the tissues; this involves the transfusion of fluids which will not rapidly leave the vascular system but which may not always contain haemoglobin in red cells. Secondly, it may be necessary to supply fluid and electrolyte substances for the maintenance or replenishment of the extravascular fluid. After injury and operation the first problem is more common, but there are occasions in many diseases when the second or both types of therapy may be indicated.

The quantity of blood lost during a surgical operation varies widely and with practice can be estimated accurately after inspection of the discarded towels and swabs. In adults, losses of less than 500 ml. usually do not call for transfusion, but when the loss exceeds 800 ml. transfusion is usually advisable, and if over 1000 ml. it is essential. Modern anaesthesia has done much to reduce operative injury and blood loss. Indeed, in the past fifteen years there has been as big a change in the post-operative condition of the patient as there has been in anaesthetic technique. Nevertheless, anaesthesia remains one of the factors which may be responsible for the production of shock in surgical operations, excessive depth of general anaesthesia or inadequate oxygen supply both leading to anoxia and depression of the higher centres. In very young or elderly patients and when surgical manipulation is rough, the duration of the operation also is an important cause of shock.

Evidence of circulatory disturbance can be obtained by observation of the colour and temperature of the skin of the lips, ears, fingers and toes, of the rate of return of colour after compression of these parts, of the incidence of sweating, and by measurement of the pulse rate and blood pressure. This evidence, moreover, is derived from the two important functional sections of the circulation, the capillaries and the large vessels, especially the arteries, and allows us to follow changes in these parts directly. If attention is confined to these observations which are clinically easy, a combination of pulse rate, blood pressure and skin colour changes, then an analysis of the predominant causal mechanism and its effects can be made in many cases of shock. No matter what the cause of the state for which resuscitation is required, it is essential to have a clear conception of the progress of the patient. We must try to imagine what has happened so far and what will happen next, both with and without treatment. If an operation is to be part of the future treatment, when will the operation be done, what does it involve and what is the minimum additional operative injury necessary? In the treatment of severely shocked persons, there should be a sense of urgency allied with calculation; the mere lapse of time seldom improves the state of an injured person. After careful assessment, an hour should be stated when it is expected that the patient will be ready for operation. That
this estimate may have to be revised according to the response of the patient to treatment detracts little from the stimulating effect of such apparent precision.

The best fluid to replace lost blood is blood. Any fluid other than blood which is to be effective in maintaining blood volume must contain some colloid which will retain fluid in the vascular system for at least some hours. Human plasma is an obvious example of this type, but it has certain disadvantages. In the past, undesirable reactions have followed plasma infusions too often to make their use free of worry or risk. In its favour it has been said that a plasma infusion can be started without the delay necessary for cross-matching blood. This advantage is possessed also by gum saline and dextran, both of which, though foreign substances, are free of the objectionable properties of plasma. Gum saline is rarely used now. Reports of the evil effects which followed the use of badly prepared gum saline have appeared at intervals since 1917. These reports, combined with the large-scale production of pooled plasma in 1940, resulted in the general abandonment of gum acacia in the treatment of shock. I have not observed any ill effects due to gum acacia in any of the patients to whom I have personally administered it, nor, when reliable preparations were used, have I been able to find evidence of undesirable reactions due to gum acacia amongst the records of a large number of infusions either before or since the war.

Dextran is a by-product of the sugar beet industry and was first manufactured for clinical use in Sweden during the war. Since 1943 it has been extensively used in Sweden and appears to be a safe and useful substance for intravenous infusion. It is believed that the long chain polysaccharide molecule of dextran is metabolised at least in part in the body and so one of the objections to gum saline, that it may not be metabolised and may be deposited in various places in the body, probably does not arise in the case of dextran. Amberson (1937) came to the conclusion that following gum saline infusion, 40 per cent. of the gum acacia left the blood in the first twenty-four hours and 60 per cent. in forty-eight hours. After the infusion of dextran there is a rapid initial loss of about 15 per cent. of the total infused due to excretion of particles of small molecular weight in the urine, and thereafter the rate of disappearance from the blood is very like that of gum. The clinical effects of gum saline and dextran also are similar, being most marked in the first twenty-four to forty-eight hours and diminishing steadily in the next three days. During the past two years I have been carrying out a clinical trial of Swedish dextran (Pharmacia). It is effective in raising the circulating volume of blood as judged by blood pressure changes and by clinical improvement of the patient. No adverse effects of any kind have been observed, there have been no urticarial or other types of reaction and at autopsy no histological evidence has been obtained of liver injury or of deposition.
of dextran in the liver or lymph glands. Clinical observation suggests that gum saline and dextran have a somewhat more prolonged effect than plasma in raising and maintaining blood volume and pressure. It also seems probable that this effect is achieved in a rather different manner.

In the treatment of traumatic shock, that is to say of shock due to injury with reduction of the blood volume, solutions of salts alone are useless (Bayliss, 1918), plasma is no better than and not as safe as gum saline or dextran, and blood is the ideal fluid in most cases.

How fast can blood be given? The answer depends on circumstances, but in acute extreme exsanguination of previously healthy subjects such as was often seen in battle casualties during the recent war, it should be given as fast as possible. I have given a pint under pressure in less than three minutes; as the second pint was started the apparently moribund patient sat up and complained of a pain in the front of his chest. Another man alive to-day in Scotland was given 5 pints in less than half an hour. If the stroke volume of the heart of an average man at rest is between 60 and 70 ml., his heart output per minute is 3.6-4.6 litres (8 or 9 pints); in muscular exercise the minute volume may be increased six to nine times and the stroke volume two to three times. There is surely ample reserve for the fastest transfusion we can achieve. Unfortunately, rate of delivery by the venous route may be limited by marked constriction of the peripheral veins. These veins are not collapsed, they are actively and firmly contracted. In severe shock it is better therefore to cannulate a vein in the upper forearm than in the leg, for the distance to the right auricle is shorter. In a severely shocked patient the vein should first be exposed through a short incision unless unusual skill is possessed in the needling of constricted veins. Delay of an hour or more in starting the transfusion due to vain attempts at inserting a needle is a common and important cause, especially in young children, of failure to give sufficient fluid fast enough to restore the patient or to save life.

Recently intra-arterial transfusion has been recommended on the grounds that it is more effective in promoting recovery than is intravenous transfusion. The available reports hardly support this, for when replacement of blood has been complete and early, the route seemed of little importance. On the other hand, following intra-arterial transfusion there have been unexplained and unpredictable rises in venous pressure, followed by death. The practice of exsanguinating the patient before or in the early stages of an operation in order to reduce bleeding during the removal of vascular intracranial neoplasms is another matter; in this the patient is bled from a cannula in a peripheral artery and later the blood is returned by the same cannula.
ILLUSTRATIVE CASES

CASE 1.—A male, aged 18, was admitted half an hour after being accidentally shot in the right lower abdomen with a small calibre pistol at very short range, the exit wound being over the third piece of sacrum. On admission the patient looked exsanguinated but no active bleeding was seen. Transfusion was started with saline while blood was cross-matched. The blood pressure was first recorded during transfusion of the fourth pint of blood. His condition improved and two and a half hours after admission the blood pressure was 104/50, but blood then began to run from the entry wound and the loss from the exit wound also increased. A few minutes later the blood pressure began to fall and it was evident that the peak of improvement had been reached so he was at once taken to the theatre. In addition to the large quantity of blood which had been lost externally from the wounds, at laparotomy over two pints of blood and clots were found in the abdominal cavity. The right external iliac artery and internal and external iliac veins were found to have been divided and there were seven lacerations of the bowel; control of the bleeding from the iliac vessels was difficult. A further three pints of blood were transfused during and just after operation. He survived but his right leg later became ischaemic and was amputated.

There are two points of interest in this case. When after an initial improvement the condition of a patient begins to deteriorate, due as in this case to the increase in the rate of bleeding consequent on partial recovery following rapid transfusion, a decision must be made at once whether attempts at resuscitation are to be continued in the hope of further improvement or whether it will be better, in spite of the poor, even precarious state of the patient, to submit him to immediate operation, stop the bleeding and then restore the depleted blood volume. This is a critical decision on which survival often depends. Recognition that the peak of improvement for a particular patient has been reached and is passing demands close and repeated observation at the bedside. The first peak of improvement by transfusion is always the highest and the ideal time to open the abdomen in such a case as this is just before the peak is gained.

For a week after injury this boy was disorientated, restless and sometimes unco-operative. This kind of mental disturbance was a common feature in badly injured soldiers in the forward areas in North-Western Europe in the summer and winter of 1944, and at that time it was attributed to the effects of the mental strain of repeated short battle actions of great intensity. It may also be due to the period of low pressure and consequent relative anoxia which, in this case, lasted for about ten hours after the injury. If so, then it is another strong argument in favour of early fast transfusion and as complete replacement of blood loss as can be achieved.

CASE 2.—A lorry driver, aged 44 (Fig. 2), began to bleed from a posterior
duodenal ulcer three weeks after closure of a perforation of another ulcer in the anterior wall of the duodenum. He was readmitted, transfused, was well for two days and apparently settled down. Then at 3 a.m. on the day of operation he had a massive melena followed by an equally large haematemesis. Two pints of blood produced only a temporary improvement and it was decided to submit him to operation.

This case emphasises what has been already mentioned, that provided active bleeding has been stopped it is easy to refill the vascular system with blood in spite of the operative interference necessary to control bleeding. This important change in possibilities is due largely to improvements in anaesthetic techniques and to the skill of the anaesthetist. No special attempt was made at resuscitation before operation. Within fifteen minutes of the induction of anaesthesia the duodenum had been opened and the bleeding vessel, a large branch of the gastro-duodenal artery, had been found and controlled. Thereafter blood pressure steadily rose during the dissection and closure of the duodenum. The fall in blood pressure while the stomach was being cleared may have been due to traction on the gastric pedicle. Instead of blood, cells were transfused during the later parts of the operation and
improvement in condition was evident by the time the wound was closed. Unfortunately the man was rolled from side to side to allow a binder to be applied. This results, as in this case, in a fall in blood pressure, an unnecessary disturbance which can be avoided if, as suggested by Cannon and others in 1917, the binder is open on the bed and the patient is laid on it when lifted from the table.

Warmth is usually recommended in the resuscitation of severely wounded and shocked patients. I wonder whether the application of warmth originated in the observation that improvement in condition was associated with a rise in the temperature of the skin. When a patient has responded to blood loss by full vasoconstriction, heating is very dangerous, a fact well appreciated by any experienced ward sister. The effect of constriction is to economise the reduced remaining volume of blood, diverting it to the tissues essential for survival. As blood volume is restored by transfusion, constriction passes off. Rather than actually warming the shocked patient it may be wiser merely to protect him from excessive external heat loss by wrapping him in blankets.

With regard to the administration of oxygen to shocked patients, Dr Lars Troell of Stockholm has been kind enough to allow me to tell you of some unpublished work of his on oxygen therapy. He has measured arteriovenous oxygen difference, oxygen consumption and cardiac output in surgical patients before and after various operations. His patients were classified according to the international method into Group I, good risk cases; Group II, moderate risk; and Group III, serious risk. No Group IV cases (very poor risk) were studied. Before operation the arteriovenous oxygen difference was similar in Groups II and III. After operation three of the six Group III patients showed an increased arteriovenous oxygen difference which was reduced by oxygen therapy. All patients, regardless of group, showed increases in oxygen consumption and in cardiac output and in all cases the oxygen content of mixed venous blood was raised to the pre-operative value by oxygen therapy. In none of the patients with increased oxygen consumption was there any clinical sign of anoxia, so no clinical sign of improvement after oxygen was evident. This work suggests that oxygen should be of value even in the absence of cyanosis, to all shocked patients, and after operation to all patients who are poor risks even in the absence of shock. It helps also to explain why there may be a poor response to transfusion when blood volume and pressure have been depressed for a long time.

In regard to the induction of anaesthesia in severely shocked patients, the anaesthetist is in the same position as Jellicoe at Jutland. In shock, pentothal is a very dangerous drug, and minimal doses only, of the order of 0.25 gm., should be given. Morphine also is a source
of danger and the use of large doses such as \( \frac{1}{2} \) grain is unwise and seldom necessary; provided the drug is given by deep intramuscular injection, absorption is satisfactory. Intravenous injection of morphine may rarely be necessary, but in severely injured men \( \frac{1}{4} \) grain intravenously may be more of an anaesthetic than an analgesic.

Subcutaneous injection should never be employed. Pain is a very variable feature following injury and morphine is not indicated if pain does not exist.

**Case 3.**—A man, aged 73, was admitted with a perforated duodenal ulcer of over twenty-four hours' duration. During the previous four months he had been vomiting repeatedly and had lost 2½ stones in weight. He was tall and thin, his skin was cold and blue, especially on the ears and fingers. The peripheral pulses and apex beat were imperceptible and the blood pressure was too small to be recorded. It was decided that he was unfit for operation and should be treated conservatively. He was given 5 bottles of dextran (1.94 litres) and the response is shown in Fig. 3. His condition remained good for about sixty hours when a slow deterioration began. On the fifth day

![Graph showing blood pressure response to dextran infusion.](image-url)
after admission it was again necessary to give him dextran, this time with much less improvement, and he died about ten hours later of peritonitis (confirmed at autopsy).

Case 4.—A boy, aged 11, went to the closet taking with him an oil lamp and a book. He placed the oil lamp on a shelf but it later fell down and ignited his clothing and he sustained burns of the trunk involving about 25 per cent. of his body surface. After local treatment he became shocked, blood pressure fell and haemoglobin concentration rose (Fig. 4). Shock progressed until he lost consciousness; it was then completely and rapidly corrected by plasma transfusion. The patient recovered.

Tissue oedema with swelling and loss of function are features of inflammation with particular significance when they involve the alimentary tract. After operation such as gastrectomy, reduction in intestinal motility leads to accumulation of gastric contents. This fluid may have to be removed by aspiration, with consequent loss to the body of electrolytes, chiefly chloride, and of water. Attempts
to correct this depletion by intravenous saline infusion leads to greater oedema of the injured gut, because where capillary permeability is most marked the saline most readily leaves the circulation. Replenishment of the extravascular source of the chloride of the gastric secretion is thus prevented. When, in addition, gastric secretion is stimulated by allowing the patient to drink freely, large quantities of water may be lost by gastric suction, amounting in one extreme example observed to over 6 litres per day. The accurate control of such a turnover with its secondary effects on fluid distribution is probably impossible; fortunately the problem can be readily resolved by stopping all oral intake.

If during the first twenty-four to thirty-six hours after gastrectomy in poor risk patients an intravenous infusion is maintained, 5 per cent. glucose solution seems to be the fluid of choice; 2000 ml. per day will provide 100 g. of glucose and ample water, and in addition will reduce the loss of sodium in the urine although that of potassium will be increased. The oral intake of fluid is kept low until gastric emptying is satisfactory.

In peritonitis, for example, after perforation of a gangrenous appendix or a duodenal ulcer, there may be a marked reduction in blood volume due to a fall in the plasma volume of as much as 30 per cent. (Wilson, 1950). This is commonly treated by the intravenous infusion of saline, but an improvement in general condition does not always result. A much more certain and lasting improvement follows the transfusion of whole blood. If the state of the patient is poor when he is admitted, blood should be given before operation rather than saline. The improvement appears to last longer if saline is not given after the blood. The same is true in the circulatory deficiency which is often seen in patients with ileus and in intestinal obstruction due either to infection or organic causes, and especially in strangulation. In elderly patients with large bowel obstruction, I have observed, on a number of occasions, a sudden appearance or increase of abdominal distention during saline infusion preparatory to laparotomy, and at operation or autopsy I have found several pints of thin brown fluid in the bowel. In all these states there is a varying length of inflamed bowel through the unusually permeable capillaries of which the infused saline will rapidly pass, increasing local oedema and reducing peristalsis. There is also, to a degree which varies with the disease, an increase in the fluid content of the bowel following saline infusion. Accumulation of contents is a prime stimulus to secretion, especially in the small intestine. I would therefore suggest that in these patients too, blood volume is restored and maintained by transfusion of blood and that water for urine formation and insensible loss is provided by infusion of 5 per cent. glucose solution, but that no attempt be made in the early stages to restore electrolyte deficiency by the infusion of large volumes of saline.
Severe alkalosis is not uncommon in surgical practice and is most commonly due to prolonged vomiting associated with pyloric stenosis; it usually becomes evident towards the end of the first week after operation. Sometimes, however, alkalosis develops in the later stages of generalised peritonitis with ileus, in some forms of intestinal obstruction or in high intestinal fistulae, especially if there have been prolonged starvation and the aspiration of gastric or intestinal secretions combined with the administration of large volumes of isotonic saline. Provided that these disturbances are of short duration, the alkalosis may be completely and readily corrected by the administration of sodium chloride. When the disturbance is prolonged however, severe potassium deficiency may also develop because loss of potassium in the gastric and intestinal aspirations and excretion of potassium in the urine continue, while intake ceases. There is a progressive removal of potassium together with water from the cells and associated with the falling intracellular content of potassium there may be an increased content of sodium (Darrow, 1945). This intracellular shift of sodium is encouraged by excessive isotonic saline administration, for not only does this increase the urinary loss of potassium but it makes a large quantity of sodium available for transfer. This sodium shift can be corrected only if intracellular sodium is replaced by potassium. This can be done by making ample potassium available through the infusion of potassium chloride solution, or if it is possible, by giving potassium chloride by mouth. These patients exhibit intense thirst which is not relieved by intravenous saline or glucose solution or by drinking, and may be so bad that they may drink their own urine. This thirst can be relieved by the consumption or infusion of a solution containing 0.4 per cent. potassium chloride, 0.2 per cent. sodium chloride and sodium lactate (Darrow). Randall et al. (1949) recommend 0.233 per cent. potassium chloride in 5 per cent. glucose solution. It is certain that isotonic saline alone does more harm than good and may kill the patient even though the urinary chloride concentration may be very low and the total daily urinary chloride output may be less than 1 gm. In acute inflammation, whether after injury or due to infection, the change in differential renal excretion renders the output of chloride in the urine useless as an indication of the bodily requirements for potassium or sodium and water.

The management of patients with small intestinal fistulae presents some interesting problems in a kind of resuscitation which is fortunately uncommon. Normally the 18 litres or so of the daily intestinal secretions are reabsorbed. With a small bowel fistula this turnover may become a loss aggravated by the secretion which follows the ingestion of any food or fluid. If oral intake is stopped, there is reduction in the loss of secretions. If the fistula is high in the duodenum or jejunum, the establishment of a jejunostomy below the fistula permits the provision
of the full daily caloric requirements and the return of the fluid collected from the fistula. When the fistula is low, some loss of secretion continues from it even when oral intake is stopped and the daily requirements must then be supplied as far as possible by intravenous infusion. It has been shown that protein hydrolysates are of limited value for this purpose because of the difficulty of providing enough calories to prevent wastage of the protein (Wilkinson et al., 1950). The chief danger, however, lies in the intravenous administration of a cumulative excess of sodium and the consequent aggravation of the potassium deficit. To prevent this, a combination of Darrow's solution with 5 per cent. glucose is the best. From time to time sudden sharp floods of intestinal fluid flow from the fistula and in a few hours a reasonably well patient may deteriorate nearly to the point of death. This seems to happen because the loss of secretions exceeds the rate at which blood volume can be restored from the extracellular fluid. The extracellular fluid itself is rapidly depleted because it takes longer still for water to be obtained from the cells. Immediate restoration of blood volume by transfusions of blood or one of the colloid-containing solutions is essential to preserve life.

The variety of forms of post-operative treatment which may be encountered in any large hospital should be a sharp reminder that patients have an astonishing ability to recover in spite of what is done to them. That so little harm has so far been done is to the credit of nature and especially of the skin and kidney.

Starvation for water and food is the natural biological state after injury and for a short period does not seem to be harmful; in the presence of this inherent ability to live endogenously for a limited time we can confer most benefit on the patient by ensuring survival by the restoration and maintenance of an adequate circulating blood volume. The accurate qualitative replacement of fluid lost by vomiting or by aspiration of intestinal secretions requires knowledge of the composition and volume of the lost fluids and specificity in the construction of the replacement solutions. The more prolonged the period during which the losses continue, the more complicated and difficult the problem of replacement becomes.

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**Discussion**

Professor Davidson said he was very glad of the opportunity of expressing his interest in Mr Wilkinson's excellent communication. We in Edinburgh were most fortunate in producing surgeons of high technical skill who, at the same time, were experimental physiologists. Professor Davidson believed that if Mr Wilkinson gave a communication on this subject to the Society two years from now he would devote a considerable part of his time to discussing the remarkable effects of ACTH and cortisone in the treatment of shock. The potent effects of cortisone in controlling capillary permeability in this condition offer a very wide field of research. Professor Davidson agreed with Mr Wilkinson that there was a real danger of giving routinely excessive quantities of saline and failing to recognise in good time the need for raising the colloid pressure of the blood by plasma or blood transfusion. Professor Davidson also agreed that the infusion of fluids to people suffering from acute blood loss and shock might be required to be given very rapidly. In medical conditions, however, in which the patient had been chronically ill for months or even years, especially when anaemia was present, rapid transfusion was very dangerous and might lead to sudden death from heart failure and pulmonary oedema. For such conditions Professor Davidson recommended a minimum of one hour for each pint of blood transfused. Professor Davidson concluded by congratulating Mr Wilkinson on the excellence of his paper.

Mr Douglas said he wished to bring up one or two points. He was surprised that if potassium infusion was required after operation presumably because of potassium deficiency there was so little evidence of excessive potassium excretion in the first few days after operation.

Another point of interest was the amount of water required by patients post-operatively. He believed the kidney to be the best judge of the water metabolism of the body. He had never come across any convincing evidence against the view that water should be given post-operatively to ensure an
output of up to one litre; this was a simple rule which, he understood, was universally held.

A third point—the question of whether dextrose was the best medium with which to make water isotonic. He was sceptical about this. If given continuously, or intermittently for long periods at a time, dextrose solutions produce intimal irritation and thrombosis; sometimes these thromboses do not remain superficial. Mr Douglas wondered whether deep thromboses post-operatively might not be related to excessive administration of sugar solutions. He wondered whether some substance such as P.A.B.A. might not be safer.

The final point Mr Douglas wished to make was the question of the stabilisation of blood pressure. He considered the blood pressure to be a poor indication of circulatory adequacy, but meantime it appeared to be the best there was. One of the main difficulties was to decide what period of stabilisation of blood pressure was necessary for a major surgical operation. He recalled one case of a wounded soldier with poor circulation whose blood stabilised at 100 mm. Hg. systolic for one hour. He was then given 2 c.c. of pentothal and died within a matter of seconds.

Dr Somerville recalled two dramatic cases he had met with in the early years of his career. The one was a case of ruptured ectopic; the peritoneal cavity was full of blood. Whilst chloroform was still being given, I began to pour saline into her elbow vein. Soon I saw she was fully conscious and asked her "Is it too hot?" She replied, "No, it is just delicious." The other was a child with severe meningitis, everything she swallowed, even water, was vomited. I asked the nurse to try half a pint of saline P.R. It was retained. Nurse gave it night and morning for eight days; then the temperature fell, the vomiting stopped and she made a good recovery.

Dr Troell stated that in Sweden dextran was much used and he had not seen any bad results, apart from an occasional case showing an allergic reaction. Some gave it regularly after operation for the first day or two. Saline was less commonly used now than hitherto. Blood transfusion was always given post-operatively in elderly patients, even if only 500 c.c. had been lost. Oxygen therapy was good, he considered, although not so important in risks 1 and 2 as in 3 and 4.

Sir Alexander Biggam remarked that in cholera it was necessary to run in saline as quickly as possible in the initial stage of treatment in order to overcome the intense dehydration which is usually present and to relieve the agonising muscular cramps.

Mr Porter said that in his experience, glucose had proved of greater value post-operatively than saline. He had often been called in to see patients who, either through ignorance or carelessness, had been given a continuous drip with saline. These cases tended to show pulmonary œdema if given excessive salt and might actually die, unless some of the excess salt could be excreted rapidly. He thought that the mercurial diuretics were of definite value in such cases.
Mr Lowdon emphasised the dangers of administration of potassium in treatment. It was necessary to give potassium at the correct time and in the right quantity because of the serious effects of overdosage. Clinical assessment of the shocked patient was of prime importance, but Mr Lowdon felt that it could be misleading if the clinician was not alert to the possibility of "hypertensive shock": in such cases it was wise to have an intravenous infusion running slowly even while patients were still hypertensive. Blood loss in elderly patients during operation was serious and it was particularly important in such patients to replace the blood as it was being lost rather than later.

In reply, Mr Wilkinson thanked those who had taken part in the discussion. He agreed with Professor Davidson that in chronic severe anaemia great caution was essential in transfusing blood; he had encountered only a few such patients, but they had always given rise to anxiety and he would suggest an even slower rate than that of one pint in one hour which had been mentioned. Mr Douglas had expressed surprise that potassium should be needed after operation although there was, he said, little evidence of potassium secretion after operation; the position was rather that potassium was only rarely required after operation and then usually because potassium loss by vomiting and in the urine had exceeded intake for some considerable period, probably several weeks, before operation. Then superimposed on this pre-operative potassium deficiency there came the continued daily loss in the urine after operation, together with the usual potassium diuresis in the first twenty-four or forty-eight hours after operation, to which might be added in some cases the additional potassium diuresis caused by saline infusions. The kidney may well be the best judge of the water requirements of the body, and it seldom required a litre of water to form obligatory urine. The average daily urine volumes found in a large number of patients during the immediate post-operative period both in Edinburgh and by Professor Wilson in Aberdeen had been 500-800 ml. The simple rule might be universally held but it was by no means universally achieved. He agreed with Mr Douglas regarding the evil effects of glucose, but doubted if the superficial chemical phlebitis ever spread into the deep veins. Phlebitis was a serious difficulty which could be reduced by using a 3 per cent. solution, and this was being investigated. He was sure Mr Douglas would allow him to disagree with him quite strongly about the value of the blood pressure as a clinical means of judging the state of the patient in acute disturbances.

Dr Troell's interesting observations that all the patients he studied were well even when their arterial oxygen content was low was the only direct evidence of this kind obtained in human patients that Mr Wilkinson had encountered, and as such was of considerable value.

In cholera saline is a peculiarly suitable replacement fluid, and it is also a feature of the disease that in those who recover, saline proves very satisfactory treatment. Mr Wilkinson wondered whether the mortality in cholera might be reduced if it was ever possible in the circumstances of an epidemic to increase blood volume in a more lasting fashion as well as to give saline.

In reply to Mr Porter, he thought mercurial diuretics might work satisfactorily after the first seven to ten days from operation, but during the first
week after operation he thought they probably had little effect because of the change in renal function.

Mr Lowdon had waved the red flag of danger over potassium administration and he was glad of this because it was potentially a dangerous substance and its ill-considered use might easily have fatal consequences. It was essential that before potassium was administered to a severely ill patient there should be a good output of urine, that is to say more than 500 ml. per day. It was easy to give too much potassium or to give it too quickly, and these risks varied inversely with the urine flow. He was glad too that the hypertensive response was emphasised for it was surely an indication for the greatest care on the part of the surgeon.