BLOOD LOSS AND BLOOD TRANSFUSION

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THE ASSESSMENT OF BLOOD LOSS FOLLOWING INJURY

The assessment of blood loss following injury may be of considerable value when considering the question of replacement of such loss. The clinical picture of "traumatic shock"—hypotension, pallor, coldness of the extremities and cyanosis, suggests that urgent treatment is necessary. However, this picture may not be evident immediately after injury, despite its severity, particularly in young healthy individuals, and its development may be delayed for some hours until the compensatory mechanism begins to fail. It is therefore of the utmost importance to have a means of assessing the probable blood loss so that treatment may be initiated before the clinical picture of "shock" has become obvious. The aim should be to obtain an estimate of the probable loss which, while it will not be exact, will nevertheless provide a reasonable basis for resuscitation.

As a guide to the volume of tissue damage the patient's hand is taken as the unit. The open hand is used as a measure of the damage in superficial wounds and the closed fist to assess the volume of bruised or pulped tissue. In a man of average size the volume of the hand is just under half a litre (Grant and Reeve, 1951). The foot, knee, forearm and upper arm are approximately equal in volume (the foot and knee each rather less and the upper arm rather more than the forearm) and each is roughly equal to 2–3 times the volume of the hand. The leg volume is 4–5 times and the thigh volume 10–12 times that of the hand.

In their report Grant and Reeve (1951) grouped injuries under four categories according to size in terms of the volume of tissue judged to be damaged:

1. Small wounds—damage less than 1 hand, blood loss seldom more than 20 per cent of the initial blood volume and commonly less than 10 per cent
2. Moderate wounds—damage of 1 or more hands but less than 3, average loss 30 per cent
3. Large wounds—damage of 3 or more hands but less than 5, average loss 40 per cent
4. Very large wounds—damage of 5 or more hands, average loss 50 per cent

They found these guides reliable in limb injuries but in dealing with abdominal injuries, where they could not be applied, their clinical assessments of blood loss were often at fault. They state that assessment must be correlated with other evidence of blood loss derived from the clinical condition of the patient, and that even if the patient does not seem ill, large and particularly very large wounds almost certainly indicate gross blood loss and the urgent need for transfusion.

Clarke and Fisher (1956) devised a method of assessing the extent of extravasation of blood into the tissues. This consists of cutting strips of felt of known but different volumes and wrapping these about the part of the normal limb to simulate the swelling of the injured limb. This can assist in the recognition of volumes of swelling in the acutely injured patient simply by sight and touch. In addition the method can be applied to the trunk. Clarke and Fisher (1956) maintain that a valuable aid to the estimation of blood loss at all stages consists in training the eyes of clinical observers to appreciate the appearance of known volumes of blood in different situations. They also suggest the use of a polythene bag to envelop the injured limb so that the blood collected in the bag can be measured.

Systolic blood pressure.

Grant and Reeve (1951) found that blood loss was in general associated with a lowered blood
pressure, their findings being that in previously untransfused patients a systolic pressure of 100 mm of mercury or more indicated a blood volume of at least 70 per cent of normal. A systolic of less than 100 mm was indicative of a blood volume of less than 70 per cent of normal.

It is not possible to obtain precise information of the patient's blood volume or haemoglobin concentration prior to injury nor is it possible to measure accurately the amount of blood lost prior to admission; therefore any estimation of the amount lost will not be exact. A reasonably accurate figure may be computed to aid decisions about treatment by taking into consideration the following:

(a) The condition of the patient, namely the condition of the skin, whether warm and dry or cold and clammy, the blood pressure, the pulse rate and volume. These must be considered with due regard for the time following injury and also the environmental conditions.

(b) Information regarding the amount of blood lost obtained from the patient himself and from observers.

(c) Assessment of the amount on clothing, dressings, etc.

(d) The extent and location of the injuries.

Assessment of blood loss at operation.

The measurement of blood lost during operation may be done by one of the following methods:

(1) Swab weighing.

(2) Weighing the patient.

(3) Estimation of the haemoglobin content of washings of swabs together with that of blood aspirated from the operation field.

(4) Blood volume estimations.

(5) The electrometric method.

(1) Swab weighing. All swabs and towels are weighed prior to use and after use, the gain in weight being taken as the weight of blood on the materials. One gram gain in weight represents approximately one millilitre of blood lost. Used swabs should be weighed without delay as evaporation will lead to error. This method of estimation is simple but has the following disadvantages: (a) a considerable error is possible because of the large number of weighings which may be necessary; (b) not all blood lost is taken up on the swabs; (c) dry swabs and towels must be used throughout; saline packs or towels will invalidate the results. Blood aspirated from the operation site must be collected and measured, and this amount added to the total.

(2) Weighing the patient. Using two hospital chair weighing machines, it is possible to estimate the total loss of body weight of the anaesthetized patient in the operating theatre in stable conditions (Rains, 1955). Corrections must be made for the amounts of fluid aspirated or given, tissues removed, dressings and ligatures added, and the loss of fluid by way of the skin and lungs.

(3) Estimation of haemoglobin content of washings of swabs together with that of blood aspirated from the operation site. By this method blood loss is estimated by washing bloodstained swabs and towels in a washing machine or tub containing a known quantity of water. The amount of haemoglobin present is proportional to the blood on the swabs and towels. Aspirated blood may be added to the tub or collected and measured separately. The haemoglobin concentration in the tub is estimated by adding either dilute alkali (alkaline haematin) or dilute acid (acid haematin) and estimating the haemoglobin by means either of an ordinary colorimeter or photo-electrically. This method of estimating blood loss requires that the patient's pre-operative haemoglobin concentration be known. It is subject to considerable inaccuracy; for example fat extracted from the swabs will interfere with light transmission, blood contained in excised tissues will not be taken into the result and may be difficult to estimate, changes in alkaline haematin occur on standing, and finally it is difficult to extract completely the haemoglobin from blood clot.

(4) Blood volume estimations. The patient's blood volume can be estimated by the use of the dye, Evan's blue (T.1824). A known amount is injected and after allowing time for mixing, the dilution of the dye by the blood gives a measure of the plasma volume. From this the blood volume can be calculated by using the haematocrit reading. This method is not easily applied to estimations of loss during operation. Inaccuracies will occur in the presence of haemolysis or lipaemic
plasma and variations in haematocrit readings, and in addition there is the difficulty of doing two estimations in a short space of time. The use of tracer elements in the estimation of blood loss offers more prospect. Red cells are labelled with 51 Cr and the loss calculated as follows:

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\text{Blood loss (ml)} = \frac{\text{Fraction of dose on swabs, etc.}}{\text{Fraction of dose per ml of blood}}
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The blood on swabs, towels etc., is measured as a whole in a ring counter (Veall and Vetter, 1958).

(5) The electrometric method. This method depends on the fact that blood is an electrolyte solution which has a constant conductivity value. Therefore, measuring the variations in conductivity resulting from the addition of blood to a liquid of known conductivity will give the blood loss. The necessary apparatus consists of a stainless steel tub fitted with a pulsator (on the principle of a washing machine) together with a measuring device. During operation all blood-stained swabs, dressings and linen are put in the tub so that the blood is washed out by means of the pulsator; blood from the operation field is carried directly to the tub by means of a suction pump. The measuring head (Wheatstone Bridge with an alternating current) estimates variations in conductivity of the liquid; the signals from the head are passed through an amplifier and fed into a servomotor which operates a pointer on a calibrated scale from which the amount of blood lost can be read. Since conductivity is increased with increasing temperature, the machine is fitted with automatic temperature compensation. The use of sodium chloride solution for moistening towels or for irrigation must be avoided. A non-electrolyte substance must be substituted and Le Veen and Rubricius (1958) recommend 2½ per cent glucose solution. The ease and accuracy of measurement with this machine is such that the method surpasses the other methods of blood loss estimation and the instrument is claimed to be accurate to one-half of 1 per cent.

**TRANSFUSION REACTIONS**

*Haemolytic reactions.*

Transfusion reactions are divided into haemolytic and non-haemolytic. A haemolytic reaction is defined as the occurrence of an increased rate of destruction of the red cells of either the donor or the recipient as a consequence of transfusion (Mollison, 1956a). Most of these reactions are due to incompatibility between the blood groups of the donor and recipient, and usually it is the donor cells which are haemolyzed. The clinical picture of a haemolytic reaction may also occur as a result of the use of over-age stored blood or of blood which has been haemolyzed by overheating.

The destruction of red cells as a result of transfusion of incompatible blood can occur intravascularly in which case haemoglobin is released into the plasma, or extravascularly in which case the red cells are withdrawn from the circulation without the appearance of haemoglobin in the plasma.

The signs and symbols of incompatibility vary considerably in severity. The usual symptoms are a feeling of coldness, perhaps associated with shivering and possibly rigor, pain in the chest and loins; sometimes the patient complains of hot flushing of the face and there may be a sense of constriction of the chest associated with loin pain.

In an anaesthetized patient, all symptoms are absent and evidence of incompatibility may not be apparent unless the reaction is so severe as to produce a dramatic fall in blood pressure; an occurrence which should suggest the possibility of a transfusion reaction in the anaesthetized patient.

Haemolytic transfusion reactions may result from (1) technical errors in grouping and crossmatching, (2) the use of group O as “universal” donor blood, (3) sensitization of the recipient by previous transfusion or pregnancy to Rhesus or other blood group systems, (4) errors of human fallibility—it is probably true to say that the majority of haemolytic reactions are due to clerical errors. These can only be minimized by the enforcement of a rigorous system of checking to ensure positive identification of the patient. Accidents have been reported in which the laboratory had prepared blood for two patients of the same surname, and because of the failure to supply adequate details of each patient the wrong blood was transfused.

Precautions to prevent haemolytic transfusion
reactions, therefore, are technical and administrative. Technical precautions consist of the adoption of a reliable method of grouping and cross-matching which should be carried out by experienced workers who are thoroughly conversant with the techniques. The use of "rapid techniques" should be avoided except in an extreme urgency. Urgent demands for cross-matched blood for transfusion can often be avoided by good planning.

Safeguarding the patient against clerical and administrative errors is very much more difficult as it is well-nigh impossible to cover all possible eventualities. Therefore it behoves those responsible to ensure that everyone involved in the handling of blood for transfusion adheres strictly to the system of checking laid down. Delegation of responsibility to junior nursing staff should be avoided. The anaesthetist should always check meticulously the patient's particulars on the bottle label with those entered on the case sheet before setting up transfusion.

It is known that a significant proportion of group O bloods contain haemolysins of sufficient potency to cause haemolytic reactions in recipients whose blood groups are other than O. Therefore, except in cases of real urgency when the ABO group of the recipient cannot be determined, group O blood should be used only for group O recipients.

Non-haemolytic reactions.

Circulatory overloading. This is by far the most dangerous of the non-haemolytic reactions and can be caused by surprisingly small amounts of blood in patients suffering from long-standing anaemia or from myocardial insufficiency. If the early signs and symptoms are not recognized and appropriate action taken, collapse and death will rapidly ensue from acute dilatation of the right heart.

This reaction can be avoided by careful assessment of the patient's condition and regulation of the volume and rate of transfusion to the capacity of the patient's heart. The first sign of cardiac embarrassment is failure of the jugular veins to empty. If this sign should be observed transfusion should be temporarily interrupted until emptying of the jugulars is re-established, after which the transfusion may be restarted but only at a very much slower rate. Should the degree of overloading have produced more severe signs, such as those of pulmonary oedema, then more active measures will be urgently necessary.

It is obvious that the immediate need is to reduce the amount of blood in the venous circulation and a useful means of achieving this is by the application of tourniquets to the limbs in such a matter as to prevent venous return but without occluding arterial flow; in this way blood will be dammed back in the extremities and the effect will be similar to a venesection.

Great care is necessary when releasing the tourniquets; this must be done very slowly. This obstruction of venous return for 25 to 30 minutes will be equivalent to a temporary venesection of about 750 ml of blood.

The usual sequence of signs and symptoms in this condition is flushing of the face, engorgement of the jugulars, a sense of constriction of the head, spreading rapidly to the chest, rapid feeble pulse, pulmonary oedema and collapse.

Air embolus. This accident is most likely to occur when positive pressure is applied to the transfusion by pumping air into the bottle. It can also occur without the application of positive pressure if the control clamp is applied high up on the delivery tube close to the bottle, so that if there should be a minute leak in the system the head of blood below the clamp may produce a negative balance whereby minute air bubbles are drawn into the stream and into the circulation; the amount of entrained air may be sufficient to produce a dangerous embolism. Placing the control clamp close to the lower end of the delivery tube will obviate the risk of this occurring and will result, at worst, in a slight leak through any defect higher up.

When positive pressure is applied to a transfusion by pumping air into the container, the risk of air embolus is considerable and it is absolutely essential that the transfusion should be closely watched by an experienced observer, and before vigilance is relaxed the pressure should be released. Air under pressure can pass into the circulation from a bottle which contains a considerable quantity of blood, the level of which may be as much as 2 inches above the outlet. The sequence of events is as follows: partial blocking of the filter results in restriction in the rate of
blood flow through the mesh so that when the blood level falls below the top of the assembly, air passes through and into the vein. For this reason positive pressure should not be maintained once the upper part of the filter assembly becomes visible above the blood.

Allergic reactions. These take the form of urticaria, oedema of the face and bronchospasm, and tend to occur most commonly in patients who are already known to be sensitive to some allergen. The reactions are rarely severe but can be very distressing to the patient. The passive transfer of sensitivity from donor to patient must also be considered (Mollison, 1956b); for this reason it is the normal practice of the National Blood Transfusion Service to reject volunteers who give a history of hypersensitivity. Munoz-Baratta (1955) concludes that allergic and pyrogenic transfusion reactions must be histaminic in type, and that their prophylaxis and treatment is affected by the use of antihistaminic drugs. He claims that good results are obtained by oral administration of antihistamine drugs and that, given parenterally either separately or combined with blood, transfusion reactions of this type are almost completely eliminated. Mollison (1956c), on the other hand, while confirming that antihistamine drugs are effective, considers it unwise to use them as a routine, as it is possible that their action may suppress the characteristic signs of the transfusion of incompatible blood.

Pyrogenic reactions. These result in a rise of temperature to more than 100°F and can best be avoided by scrupulous care in the cleaning of the transfusion equipment and in the preparation of the anticoagulant agent. Distilled water must be freshly prepared and the solutions autoclaved as soon as possible after preparation. All apparatus, glass, rubber tubing and needles must be thoroughly cleaned and receive a final rinse of distilled water, followed by drying, assembly and autoclaving.

A slow rate of transfusion, where possible, will reduce the risk of pyrogenic reactions. In addition it is well known that the severity of pyrogenic reactions can be reduced by keeping the patient warm, even a little warmer than comfortable.

Antihistamine drugs are of value in patients who have suffered this type of reaction from previous transfusions and the administration of such drugs before transfusion will at least mitigate the reactions and will in many instances completely prevent their occurrence.

Safeguarding of the patient against transfusion accidents and reaction depends on the exercise of meticulous care in the preparation of apparatus, the collection and subsequent storage and handling of the blood, strict attention to detail in collecting and identification of specimens, a reliable cross-matching technique, adequate checking to ensure that the correct blood is given, and continuous supervision throughout the duration of the transfusion by experienced personnel.

BLOOD SUBSTITUTES

Plasma. The best substitute for whole blood is plasma, since it will restore and maintain the blood volume in the same way as transfusion of whole blood. Ideally in the treatment of severe blood loss where considerable quantities of fluid are needed, blood should also be given in the proportion of one bottle of blood to two, or at most three, of plasma in order to prevent dangerous haemodilution. Otherwise the properties of plasma are such that it will restore lost volumes and sustain the increase as well as whole blood by virtue of its similar protein content and osmotic pressure. In view of its properties it would be thought that plasma would be used more extensively than is at present the case, the reluctance to use it, in preference to plasma substitutes, to augment blood, stems from the mistaken impression that the risk of transmitting homologous serum jaundice is very much greater with plasma than it is with whole blood. This impression dates from the war and immediate post-war years when the plasma available was derived from the bloods of at least 300 donors; this was known as large pool plasma, and its use resulted in a jaundice incidence of up to 12 per cent (Lehane et al., 1949). However, the plasma now available is derived from the bloods of not more than ten donors, small pool plasma, and it has been found that the incidence of jaundice following its use is not significantly different from that which occurs when whole blood alone is used. In two surveys the incidence of jaundice was as follows: whole blood 0.8 per cent, small pool plasma 1.2 per cent (Lehane et al., 1949); whole blood 0.16 per cent, small pool plasma with or without blood
0.12 per cent (Medical Research Council, 1954). Therefore it would seem reasonable to state that small pool plasma might well be safer than inadequately matched blood, and that where the immediately available supplies of blood were insufficient for an emergency, plasma is the ideal substitute.

**Dextran.** This is a synthetic substance, the molecules of which are long chains of glucose units; the British product has an average molecular weight of about 200,000. It is a safe and satisfactory substitute for plasma, and although large amounts are said to prolong bleeding time, there is no evidence that moderate amounts have this effect. Bull et al. (1949) found that the plasma protein level was reduced after infusion of dextran and rose slowly again as the dextran was eliminated, thus the total of protein plus dextran tended to remain constant. Although dextran is incorporated in the tissues there is no evidence that it causes histological changes. As reactions to dextran are very uncommon, it may be said to be a safe substitute for plasma which will give good results.

**Plasmasan (Polyvinylpyrrolidone).** This substance has been used extensively on the Continent for several years but it appears to be less well retained in the circulation than dextran. It is therefore a less satisfactory plasma substitute.

**TRANSFUSION APPARATUS**

The present standard glass-rubber transfusion administration set fitted with either a wire gauze or gas-mantle type internal filter is now being replaced by a plastic disposable set with an external nylon filter. This new set also differs from the glass-rubber set in that it has a combined air inlet and blood outlet needle which is pushed through the rubber diaphragm of the bottle, whereas in the glass-rubber set there is a rubber bung carrying both a blood outlet and an air inlet of glass tubing.

Experience with the new plastic sets, which are at present manufactured only by Messrs. Capon Heaton, of Birmingham, indicates that they are very satisfactory and are in general preferred to the older set.

There are many varieties of plastic set of Continental or American manufacture, some of which have what appear to be inadequate filters. Of the American sets the "Plexitron" No. R48, marketed by Baxters, which combines a pressure pump as shown in figure 1, is now obtainable in this country. The pump in this set is part of the combined drip counter-filter chamber and consists of a plastic ball which floats up and closes the inlet when a pumping action is applied to the flexible chamber thereby filling it with blood. In a limited trial this set worked very satisfactorily and it has the merit that there is no risk of producing air embolus when positive pressure is applied.

The Fenwal plastic set is an all-plastic unit including the blood container; this type of unit is also available and is supplied ready charged with the necessary anticoagulant agent and is fitted with a blood collecting attachment. The administration set is a separate unit which when required must be attached to the container by puncturing a diaphragm in a special port in the bag. These units have the merit that there is no air in the
container and there is no need for venting as the bag is flexible. Positive pressure can be applied simply by compressing the bag between two flat surfaces or by placing the bag under the patient's buttock. This type of set is not suitable for use at blood-collecting sessions where large numbers of donors are dealt with, because it is necessary after venepuncture to displace a bead valve fitted in the tubing before the blood can enter the bag. This manoeuvre sometimes presents considerable difficulty thus necessitating the spending of more time with each donor than is practicable.

METHODS OF APPLYING POSITIVE PRESSURE

Positive pressure. This may be necessary when the restoration of lost volume is a matter of urgency demanding a rapid rate of transfusion. With massive haemorrhage there will be very marked venespasm and it is advisable if possible to avoid attempts at transfusion through the veins of the leg, as it can present extreme difficulty and indeed it may be impossible to overcome the venespasm.

The most convenient and readily available method of applying positive pressure without special apparatus is to apply the bulb unit of a sphygmomanometer to the air inlet tube of the set and to pump air into the bottle. This method is effective but as mentioned earlier requires very careful supervision if the risk of producing air embolus is to be avoided.

Positive pressure may also be applied by using a roller type pump like the Martin's pump, which is used fairly extensively. This pump provides satisfactory positive pressure, but is not entirely free from the risk of producing air embolus as it is possible to entrain air if the level of blood in the drip chamber falls below the outlet.

The application of positive pressure to transfusion by means of the Baxter administration set or by compression of a plastic blood container, as for example the Fenwal Pack, is free from the risk of air embolus; nevertheless it is imperative that the patient should be watched closely for signs of cardiac embarrassment by an experienced observer throughout the procedure.

When air is used to produce positive pressure the necessity for vigilance cannot be overstressed and the responsibility for maintaining supervision should never be delegated to junior medical or to nursing staff.

REFERENCES


