Equipment

Intraoperative reinfusion of whole blood using a new autoinfusion device

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Aortic aneurysm resection is frequently associated with considerable blood loss and requires transfusion. To minimize complications and cost many institutions use a "cell saving" method that allows reinfusion of the washed red cell fraction of blood suctioned from the operative field. The disadvantages of this technique are that homologous transfusion is regularly required to replace platelets and coagulation factors. Red cell transfusion may also be required when there is rapid major blood loss as the wash cycle may be too long to subject a patient, in a high-risk group for coronary artery disease, to anaemia. A new autoinfusion device anticoagulates blood as it is suctioned from the operative field then filters, defoams, and returns it whole to the patient without a processing time lapse. We successfully used the device in a patient for aortic aneurysm resection to reinfuse two-thirds of his blood volume shed over 80 min. Neither banked red cells nor plasma were used. His haematocrit and coagulation profile remained stable throughout surgery and recovery. The potential complications and cost of homologous transfusion were avoided.

La résection d'un anévrysme aortique est souvent associée à des pertes sanguines considérables et à l'administration de transfusions. Pour minimiser les complications et les coûts, plusieurs institutions utilisent des récupérateutrs de cellules (cell savers) qui permettent la reperfusion des cellules lavées aspirées du site chirurgical. Par contre, cette technique a ses désavantages car il faut quelquefois avoir recours à des transfusions de sang homologue pour remplacer les plaquettes et les facteurs de coagulation. Des transfusions peuvent aussi être nécessitées par une perte rapide de sang qui dépasse en vitesse les cycles du lavage chez les coronariens qui supportent mal l'anémie. Un nouvel appareil d'autotransfusion anticoagule le sang à mesure qu'il est aspiré, le filtre, le démousse et le retourne au patient sans délai. Nous avons utilisé avec succès cet appareil sur un patient pour lui retransfuser les deux tiers de son volume sanguin perdu en 80 minutes. On n'a pas utilisé de sang conservé, ni de plasma. L'hématocrite et le coagulogramme sont demeurés stables pendant la chirurgie et à la phase de réveil. On a peut-être ainsi évité les complications et le coût reliés aux transfusions de sang homologue.

Key words
EQUIPMENT: infusion systems;
TRANSFUSION: autotransfusion.

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For almost 200 yr efforts have been made to combat hemorrhagic shock by reinfusing shed blood. Interest in this form of autologous transfusion diminished as effective typing and crossmatching led to a readily available blood supply. A resurgence of interest in the use of autologous blood has occurred due to awareness of the potential for transfusion reactions and disease transmission with banked blood, an increasing demand for blood associated with inadequate supply, and occasional patient antibodies which may make crossmatching difficult. Autologous blood is not associated with these problems and its use can drastically reduce demands on the blood bank.

Autologous transfusion is considered in the perioperative period if considerable blood loss is anticipated. It may be accomplished by the following methods either alone or in combination: (a) preoperative donation over time of one or more units of blood, (b) donation in the operating room prior to surgery with maintenance of normal blood volume, and (c) salvage and return to the patient of blood shed during the operation. In recent years the "Cell Saver" (Haemonetics Corp, Natick, Ma.) has been used almost exclusively for the latter technique.

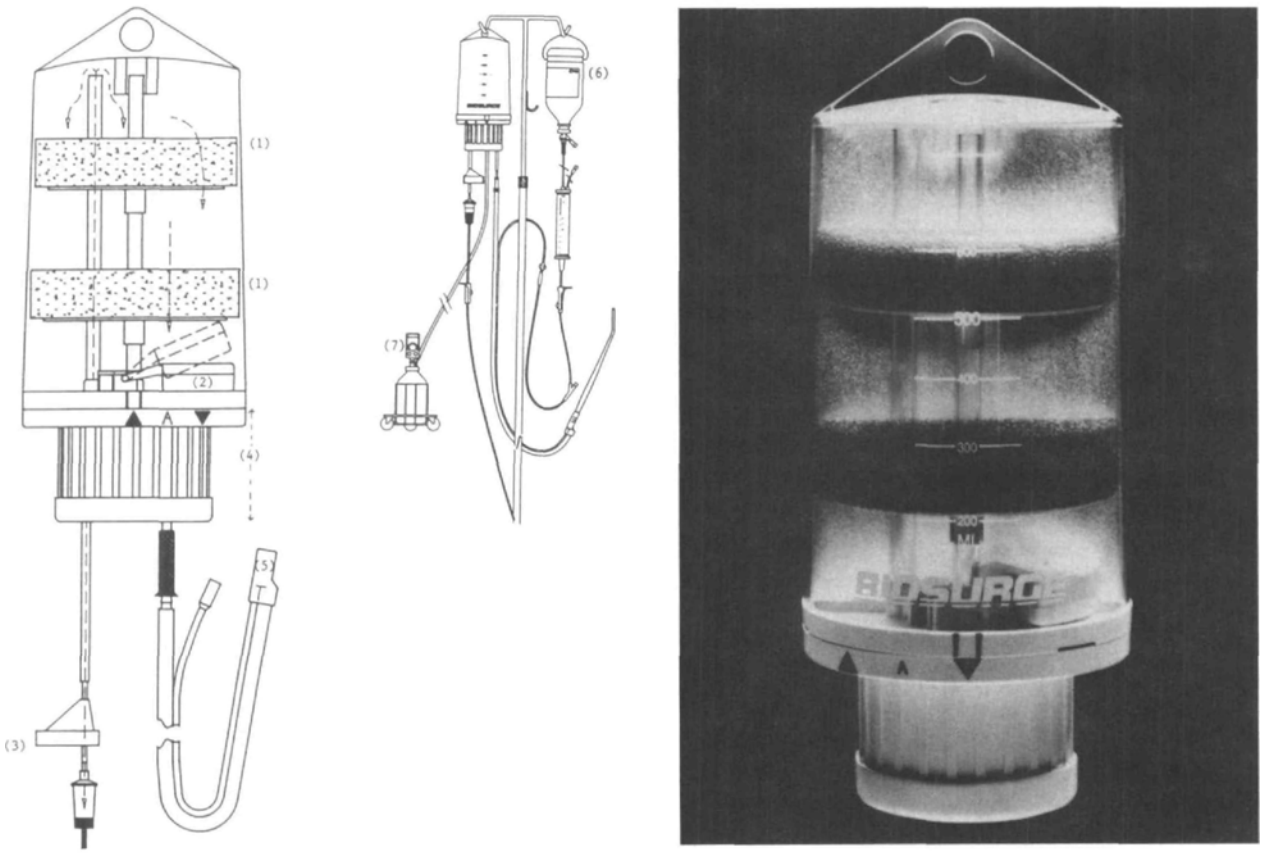

FIGURE "Biosurge" autotransfuser with pointer indicating chamber A in blood aspiration mode in diagram and infusion mode in the photograph. (1) Defoaming filters; (2) float valve; (3) 40 μ filter; (4) chamber changing rotator; (5) suction wand; (6) CPD reservoir; (7) vacuum regulating valve; (8) 60 ml compressible chamber.

We describe in this report the use of a new device, "The Biosurge" (Deknatel, Inc. Fall River Mass.). Using this device, we were able to salvage and return to a patient, over an 80-min period, approximately two-thirds of his blood volume (3900 ml whole blood), and avoid using both homologous red cells and coagulation factors.

Device description

The Biosurge (Figure) is a cylindrical device that is bisected vertically into identical containers A and B, each having a volume of 700 ml. Each container has two ports. Container A has one port attached to the operating room vacuum supply via a pressure-limiting regulator set at no less than negative 100 mmHg. The other port is attached to the suction wand on the surgical field. Blood enters the top of the container first, then passes to the bottom through two polyurethane defoaming filters. Citrate phosphate dextrose anticoagulant (CPD) is added to the blood during collection via a small-bore tubing that terminates at the suction wand and is supplied from a 100 ml burette attached to a 500 ml bag of CPD. The rate of flow of CPD is regulated manually by a simple roller clamp.

When chamber A is full, a rotating mechanism at the base converts it into a blood infusing device by connecting one of its ports to a blood administration set via a 40 micron filter and its other port to a filtered air vent. We use a blood administration set that incorporates a manually compressible 60 ml chamber with a one way valve; this set can be used to increase the rate of reinfusion. The rotation changes chamber B into the new aspiration chamber. In this way aspiration and reinfusion occur simultaneously. The rotating mechanism also allows some leeway during periods of high blood loss, as the reinfusing chamber does not necessarily have to be empty before changing it to a collecting chamber if the other chamber is nearing capacity.

Before use, both chambers must be primed with saline to wet the defoaming filters and fill the blood administration set. This is done either by aspirating sterile saline from a container on the sterile surgical field or by connecting a bag of sterile saline to the CPD tubing. Wetting

TABLE Perioperative haematocrit and coagulation values

Time	*HCT%*	*PT sec.*	*PTT sec.*	*Fibrinogen mg · dl^{-1}*	*Platelets 1000 mm^{-3}*
Normal ranges	40–50	9–11	24–35	150–400	150–400
Preoperative	45	10.6	27.6	*	370
Reinfusion volumes					
1500 ml	38	11.8	116	366	174
2400 ml	36	12.1	83.8	298	156
3500 ml	36	11.6	49.6	300	222
3900 ml	35	11.2	37.9	*	237
Postoperative days					
1	33	10.5	24.8	*	228
2	34	10.8	28.8	*	248
3	30	10.9	32.5	*	252
4	34	*	*	*	*
5	33	*	*	*	*

The effects of reinfusing large volumes of autologous whole blood on haematocrit and coagulation values.
*Test not performed.

the defoaming filters with saline prior to blood contact is essential for their proper function by preventing filter dehydration of the initial aspirate. Fifteen ml CPD is then added to each chamber. Once aspiration of blood begins, CPD flow is set at a minimum of 2 ml · min^{-1}. During brisk blood loss the flow is increased to maintain the overall CPD:blood ratio at 1:5 to 1:10. Adjustments are regularly required based on observation of the volumes of aspirated blood and consumed CPD.

Case report

A 63-yr-old man presented for resection of a large infrarenal aortic aneurysm. Other relevant medical conditions included gout, ankylosing spondylitis, paroxysmal atrial fibrillation and a moderate-sized but mild inferior myocardial perfusion defect on a recent persantine-thallium scan. Preoperative haematology and coagulation values are listed in the Table. Blood chemistry values were normal. In addition to ECG oximetry and capnometry, perioperative invasive cardiac monitoring with pulmonary and radial artery catheters was employed. Two 14-gauge peripheral intravenous lines were placed. General anaesthesia was induced with fentanyl and midazolam and was maintained with fentanyl, nitrous oxide and isoflurane with controlled ventilation. Tracheal intubation was facilitated with vecuronium.

Before skin incision, the Biosurge autotransfusion device was primed as described above. Mannitol 12.5 g and heparin 5000 u were given *iv* before aortic crossclamping. Crossclamp time was 80 min during which blood loss was brisk because of the presence of large lumbar vessels. Blood loss was slightly greater than the 4400 ml salvaged by the autotransfusion device of which 3900 ml was reinfused. The reinfusion was stopped at 3900 ml because we noticed coagulum development on the top filter of the device. The device was set up to deliver CPD anticoagulant at approximately 2 ml · min^{-1} to the suction tip. The flow rate was adjusted upward frequently to match blood loss; a total of 460 ml of CPD was used. This gave a CPD:blood ratio of 1:9.5, which reaches the upper limit of the range of 1:5 to 1:10 recommended by the manufacturer. A ratio of 1:7 is recommended by Jacobs *et al.*[1] and a similar ratio is used in blood banking. All blood volumes referred to do not include added CPD.

Haematocrit levels were checked on the blood returning to the patient at reinfusion volumes of 1500 ml, 2400 ml and 3500 ml and were 27%, 28%, and 31% respectively. Laboratory examination of a smear made from this blood at reinfusion level of 1500 ml showed mild red cell crenation with no debris and a platelet count of 85,000 mm^{-3}. Arterial blood samples taken at the same times and at the end of the procedure when 3900 ml had been reinfused were checked for haematocrit, PT, PTT, platelets and fibrinogen. The results are shown in the Table followed by laboratory values obtained until the patient's discharge from the hospital on postoperative day 5.

Arterial blood gases and electrolytes were checked at regular intervals intraoperatively and remained normal. Calcium chloride 1 g was given *iv* when serum ionized calcium decreased to 2.9 mg · dl^{-1} after 3000 ml had been reinfused from the Biosurge.

Discussion

The practice of autotransfusion was first reported by Blundell, a London physician, in 1818.[2] Other early reports were by Duncan of Glasgow who in 1886 resuscitated a moribund amputee by injecting shed blood into a vein in the amputation stump[3] and by the German

physician Elmendorf who in 1917 returned the chest drainage of trauma patients with haemothoraces.[4] By 1936, 279 cases of intraoperative autotransfusion had been reported in the US medical literature.[5] The practice of autotransfusion then waned as an understanding of blood types and storage led to the development of blood banks. Interest in autotransfusion again increased in the early 1960s because of the potential for disease transmission by homologous blood and the demonstration that blood could be circulated outside the body and safely returned when properly anticoagulated during cardiopulmonary bypass. In the 1960s in Vietnam, Klebanoff used a roller pump technique similar to one used during cardiopulmonary bypass to reinfuse blood which had been aspirated from the surgical field.[6] The Bentley Autotransfusion Device (Bentley Labs., Santa Ana, CA), based on Klebanoff's work, was widely used for some years. Brewster *et al.* at the Massachusetts General Hospital successfully used it on 150 patients and recommended its use as a safe, cost-effective autotransfusion device.[7] Because of reports of air embolism caused by the roller pump, the device was withdrawn from the market.[1] A "cell saver" device based on 1968 Mayo Clinic research[8] was developed by Haemonetics Corp. (Natick, Mass.). This apparatus washed and saved the red cell fraction of blood which was then returned to the patient. This device is still widely used. The Biosurge autotransfusion device is the most recent development. Unlike the cell saver, it returns whole blood to the patient.

Many factors must be considered when autotransfusing large volumes and the potential for coagulopathy is a major concern. A dilutional coagulopathy will develop as the volume transfused increases. This may lead to further patient exposure to homologous blood if blood fractions such as platelets are required. Results using the Bentley autotransfuser[7] and our case demonstrate that use of a whole blood autotransfuser is less likely to lead to patient exposure to donor blood or blood products. The coagulation profile in our patient remained stable during and after the operation. The small elevation in PT, the initial large increase in PTT and the gradual return of both to normal values was a consequence of the 5000 u of heparin given just prior to crossclamping. Heparin also negates the effects of procoagulant released during blood exposure to air and foreign surfaces and this was probably very helpful in maintaining platelets and coagulant factor concentrations near normal in the salvaged blood.

Considerable plasma-free haemoglobin and urinary haemoglobin have been reported after intraoperative autotransfusion using the Bentley device.[7] However, the free haemoglobin was not associated with renal damage and was cleared from blood and urine within 24 hr. Its presence was linked to red cell damage by roller compression and high-pressure suction and infusion. In our patient the smear performed on the infusing blood showed mild crenation of the red blood cells. Crenation is a reversible process[9] and no free haemoglobin was detected in the urine. Haematocrit remained stable close to preoperative levels, and additional spun haematocrits performed in the operating room for closer monitoring showed clear plasma. Therefore, it is unlikely that there was any significant haemolysis. Our patient was ideally suited to whole blood autotransfusion:[10] aortic aneurysm surgery is associated with a large blood loss that pools in the peritoneal cavity; relatively low suction pressure can be used; the suction tip can be kept under the surface of the blood to minimize air contact and foaming; and the blood is already heparinized preventing coagulation activity even before contact with CPD, thus preventing factor depletion.

The cause of the coagulum formation is uncertain, but the following factors may have contributed; the heparin effect was wearing off as the reinfused volume approached 3900 ml^{-1} and the PTT at this point was practically within normal range (Table); the quantity of CPD used was the minimum recommended and it is possible that during periods of maximum use that the CPD:blood ratio may for brief periods have been less than 1:10 because adjustments at such times may not be precise. Theoretically, therefore, even greater vigilance should be exercised if using the Biosurge without systemic heparinisation in other surgical procedures associated with less blood pooling and consequently more extravascular tissue exposure and greater foaming.

Contraindications to the use of autologous blood include bacterial contamination, such as blood salvaged near a perforated bowel, and blood salvaged during cancer surgery. The use of microfibrillar collagen haemostatic material is an absolute contraindication. In autotransfused animals this has lead to brain infarction.[11]

The Biosurge Autotransfuser is the newest of these devices. It is easy to set up and use, and it protected our patient from exposure to multiple units of donor red cells, fresh frozen plasma and platelets. It was more effective than the cell saver device because fresh frozen plasma was not required and because there was no lag time between retrieval of blood and its reinfusion. Care should be exercised in its use particularly with regard to both clinical and laboratory monitoring for development of coagulopathy. During periods of rapid blood loss and reinfusion it requires the full-time attention of an anaesthesia team member.

In the US a unit of red blood cells costs $216.00; a unit of fresh frozen plasma $251.00 and platelets cost between $1500.00 and $2000.00 per transfusion after sin-

gle donor pheresis. Demand for blood products in many states outstrips supply. The Biosurge device costs $280.00. The use of autotransfusion is not only cost-effective but highly desirable in reducing demands on the blood bank and in limiting patient exposure to donor blood and blood products.

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