Technique

A Modified Collection and Rapid Infusion System for Shed Whole Blood Autotransfusion During Aortic Aneurysm Surgery

René J. Dekkers, BS, CCP*; Robert J. Rizzo, MD+, Daniel J. Fitzgerald, CCP*, Lawrence H. Cohn, MD+

Departments of Cardiac Perfusion* and Cardiac Surgery+, Brigham and Women's Hospital, Harvard Medical School, Boston, Massachusetts

Keywords: blood transfusion, aortic surgery, autotransfusion, ultrafiltration

Presented at the 33rd AmSECT International Conference, Orlando, Florida, April 27-30, 1995; Winner of the 1995 Fellowship Award forr the Outstanding Presentation at the Conference

ABSTRACT

We describe our experience in 10 patients (5 males) undergoing resection of a descending thoracic aortic aneurysm or a thoracoabdominal aortic aneurysm in which a modified shed whole blood collection and autotransfusion system was used. This modification allows several options for the processing and autotransfusion of shed blood: use of the cell saving device or the ultrafiltration of collected blood, and the autotransfusion of unprocessed shed whole blood. Either low dose heparin or sodium citrate was used for anticoagulation.

All 10 patients underwent autotransfusion and volume resuscitation with the modified rapid infusion device. Total autotransfusion ranged from 1400 ml to 7843 ml. Ultrafiltration volumes ranged from 600 ml to 1100 ml. There were no intraoperative deaths and no patient reoperations for bleeding. Arterial blood gases, potassium, and platelet counts were all within the normal laboratory ranges. This modification enables the clinician to process poor quality shed blood and reinfuse whole blood, in an attempt to decrease the need for homologous blood products.

Address all correspondence to:
René J. Dekkers, BS, CCP
Division of Cardiac Surgery
Brigham and Women's Hospital
75 Francis Street
Boston, MA 02115

INTRODUCTION

There is considerable data regarding the blood loss associated with the morbidity and mortality in patients who undergo descending aortic surgery. The Baylor surgical group has reported that the average blood component utilization in repairs of the descending thoracic aorta is 10 units of packed red cells, 7.2 units of fresh frozen plasma, and 13 units of platelets (1).

In a large retrospective analysis of thoracoabdominal aorta surgery, between 1960-1991, the variables associated with death included increasing age, renal function, and bleeding. The blood and blood product usage required for these patients undergoing aortic surgery was considerable. The median number of blood products administered was: 7 units packed red cells (range: 1-46 units), 16 units fresh frozen plasma (range: 0-132 units), 20 units platelets (range: 0-110 units), 0 units cryoprecipitate (range: 0-100 units), and 8 units operative cell washing (range: 0-68 units). The massive transfusion required by these patients can cause hemostatic failure, electrolyte imbalance, acidosis, hypocalcemia, hyperkalemia, and hypothermia (2).

Shed blood during aortic surgery tends to be of a higher quality when compared to shed blood from most other surgery. This is mostly due to the fact that shed blood during aortic surgery is usually uncontaminated by irrigating fluids or body fluids. Intraoperative salvage and washing of shed blood (ie. cell washing device) during the operative procedure is the most common technique for blood conservation. The disadvantages with this technique—loss of plasma proteins, processing time required and platelet loss—become even more significant during massive blood loss. It is not uncommon to process as many as 20-30 units of intraoperative cell washed blood during aortic surgery. Thus, there is a need for a collection and reinfusion system that would salvage shed whole blood while maintaining plasma protein levels and reinfuse shed whole blood in a safe and rapid normothermic manner.

One manufacturer has developed a rapid infusion device (RID) capable of providing rapid normothermic volume replacement. The rapid infusion device was designed to provide immediate volume resuscitation by delivering up to 1500 ml/min of normothermic fluid. It has demonstrated usefulness in a variety of procedures outlined in Table 1. It also provides the user control over flow rate, temperature of infusate, and a visual display of total transfused volume (3).

The design of the RID, however, has been limited to a transfusion device and not as a collection device. We determined a need for a device that would anticoagulate and collect shed whole blood, then warm, filter, and reinfuse the shed blood back to the patient in a safe and rapid fashion. This would aid in decreasing the need for homologous blood administration and would aid in sparing plasma proteins and platelets lost during the cell saving process. Table 2 lists procedures where this modified system might work. This article continues to examine the technique we initially described (4).

Table 1: Indications for Rapid Infusion System

1. Thoraco-Abdominal Aorta Surgery
2. Liver Transplantation
3. Extensive Vascular Surgery
4. Trauma
5. Cardiac Surgery
6. Assisted Circulation
7. Burn Surgery

Table 2: Suggested Indications for Modified Rapid Infusion System

1. Thoraco-Abdominal Aorta Surgery
2. Liver Transplantation
3. Extensive Vascular Surgery

MATERIALS AND METHODS

A retrospective review was done on 10 patients (5 male) who underwent resection of a descending thoracic aortic aneurysm. All ten patients were volume resuscitated with the modified collection and reinfusion system[a]. All patients received left atrial-femoral artery distal perfusion with a constrained vortex

a Haemonetics Corporation, Braintree, MD

Table 3: Patient demographics

Characteristics	Range	Mean (SD)
Age (years)	63-77	69.3 (4.9)
Weight (kg)	54-98	74 (14.8)
Body Surface Area (m^2)	1.30-2.2	1.80 (.32)
Preoperative Hematocrit	29-40	32.7 (4.4)
Postoperative Hematocrit	19-32	27.6 (4.83)
Preoperative PT (sec)	11.8-15.7	13.8 (1.27)
Preoperative PPT (sec)	26.7-40	31.9 (4.84)
Postoperative PT (sec)	13.6-19	15.4 (2.0)
Postoperative PPT (sec)	25.9-64	39.5 (10.4)
ACT baseline (sec)	97-201	123.7 (30.1)
ACT post-heparin (sec)	213-476	270.1 (87.1)
Anticoagulant (CPD/Heparin)	2 pts Heparin	8 pts CPD
Preoperative Platelet count (x 10^9/ml)	144-488	253.3 (117.9)
Postoperative Platelet count (x 10^9/ml)	83-191	127 (39.84)
Aortic cross-clamp time (min)	31-127	60 (27.6)

N = 10
(SD) = Standard Deviation

blood pump[b]. Patients were categorized retrospectively into two groups; in five patients no additional roller pump was used (Group 1), and in five patients an additional roller pump was placed between the collection cardiotomy reservoir and the reinfusion cardiotomy resorvoir (Group 2). The patients' demographic data are given in Table 3. Management of the RID is simple and requires only 5-10 minutes of preparation and prime time. The RID will deliver infusate at a rate of up to 1500 ml/min in the normothermic range. Infusion rate can be controlled manually or in 100 ml or 500 ml boluses. Infusion will not be permitted if the reservoir contains less than 200 ml of fluid, air is sensed, the temperature of the infusate is less than 34°C, or if line pressure is greater than the preset limit.

RID Modification:

With both Group 1 and Group 2, we mounted to the RID an additional 2600 ml 150u filtered cardiotomy reservoir[a] which was now our collection cardiotomy resorvoir. Regulated wall suction (≈150 mmHg) was connected and applied to the collection cardiotomy reservoir via the vacuum port. Sterile aspiration suction tubing was passed off from the surgical field and connected to any of the four filtered ports of the reservoir.

Anticoagulation was in the form of either low dose heparin (30,000u/liter of saline) or sodium citrate (10g/250ml) with average drip rate of about 5ml/min, during blood collection. In Group 1 the collection cardiotomy reservoir was connected to the reinfusion cardiotomy reservoir via a y-connector, allowing the versatility to drain contents via gravity into either the reinfusion cardiotomy reservoir or to the cell washing device for processing (Figure 1). In Group 2, the y-connector allowed the shuttling of collected shed blood from the collection cardiotomy reservoir to either the reinfusion cardiotomy reservoir actively via a roller pump or to the cell washing device (Figure 2). Reinfusion via the modified RID ceases and the shed blood is diverted to the cell washing device for processing during the periods of initial dissection and at the onset of protamine administration.

With Group 1, when a significant amount of shed whole blood had entered the collection cardiotomy reservoir, regulated suction to the surgical field had to be interrupted to allow for active drainage into the reinfusion cardiotomy reservoir. With Group 2, the additional roller pump was activated to actively shuttle shed whole blood from the collection cardiotomy reservoir to the reinfusion cardiotomy reservoir without interrupting suction to the surgical field.

When shed whole blood entered the reinfusion cardiotomy reservoir, the contents were either rewarmed and filtered (40u filter) and reinfused to the patient or rewarmed, filtered, and recirculated through a .6 m^2 hemoconcentrator[c] which was placed into the recirculation line prior to reinfusion to the patient. This technique assures that the shed whole blood to be reinfused is warmed to 37°C and that any excessive crystalloid fluid scavenged at the operative field will be removed.

b Medtronic, Inc., Anaheim, CA
c Diafilter-30, Limerick, Ireland

Figure 1: Schematic diagram of modified rapid infusion device without additional roller pump (Group 1)

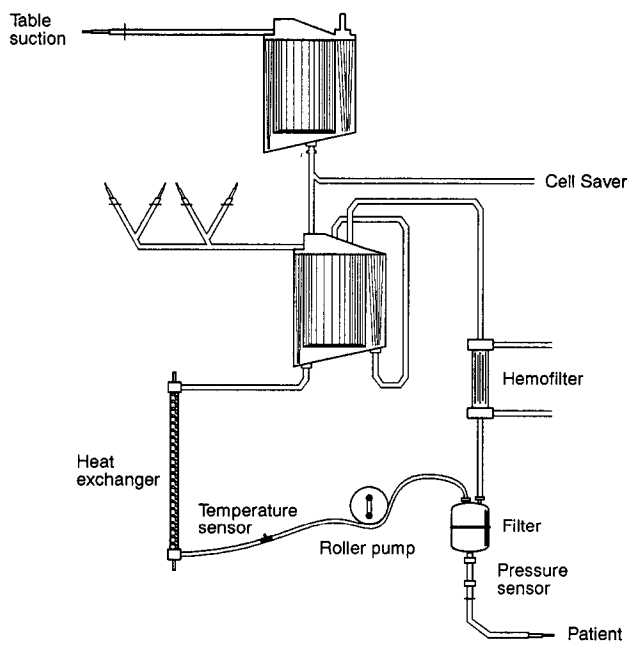
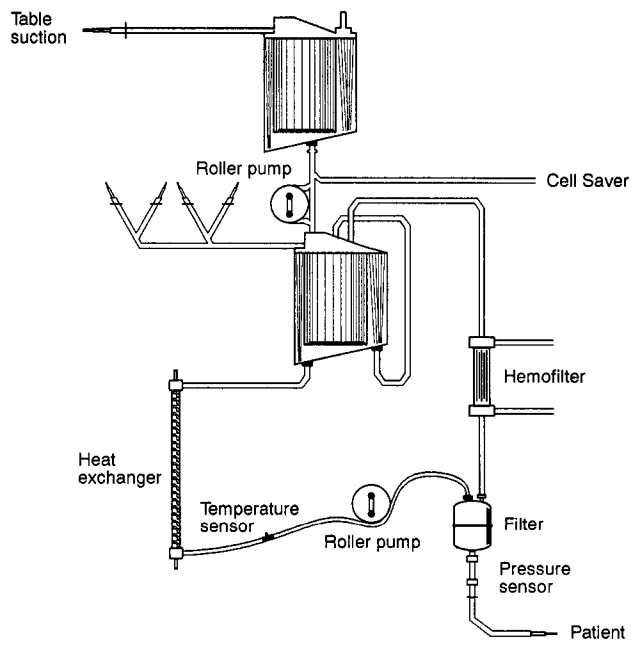


Figure 2: Schematic diagram of modified rapid infusion device with additional roller pump (Group 2)



RESULTS:

All ten patients underwent autotransfusion and volume resuscitation with the modified RID. Total autotransfusion volumes ranged from 1400 ml to 7843 ml. Ultrafiltration was performed in three patients and ultrafiltration volumes ranged from 600 ml to 5100 ml (Table 4). There were no intraoperative deaths and no patient reoperations for bleeding. There was no postoperative morbidity. Aneurysms ranged from 3.0-7.0 cm in size. All patients were given 5000u of porcine heparin prior to cannulation for left heart bypass. Patient age ranged from 64-74 years old; five were males. BSA ranged from $1.3m^2$-$2.2m^2$. Cross clamp time ranged from 44-132 minutes. Table 4 summarizes the intraoperative blood product administration.

Table 4: Intraoperative Blood Administration

Blood Product	Range	Mean (SD)
Volume Reinfused (ml)	1400-7843	4018 (1894)
Volume Ultrafiltrated (ml)	600-1100	866 (435.1)
Homologous Packed Red Blood Cells (units)	0-12	3.3 (3.4)
Homologous Fresh Frozen Plasma (units)	0-8	1.4 (2.67)
Homologous Platelets (units)	0-12	2.4 (4.2)
Homologous Cryoprecipitate (units)	0-0	0 (0)

N = 10
(SD) = Standard Deviation

Arterial blood gases and potassium remained within normal range. Because

to sodium citrate as the shed blood anticoagulant in subsequent patients. Moderate volumes of citrate will cause ionized calcium levels to be depressed, thus ionized calcium levels were monitored at baseline as well as at 30 minute intervals during the procedure and more frequently depending upon the quantity of blood reinfused.

DISCUSSION

It has been previously mentioned that surgery involving both the thoracoabdominal aorta or the descending thoracic aorta can lead to both massive and sometimes uncontrollable hemorrhage and significant coagulopathies. The described modified shed whole blood collection and reinfusion system has been beneficial in maintaining both hemostasis and hemodynamics during this type of surgery. The modified system allows several options for dealing with the varied quality of collected shed whole blood prior to reinfusion. The clinician can utilize either a cell washing device to formally wash the blood, the hemoconcentrator to ultrafiltrate crystalloid contaminated blood, or the modified rapid infusion system to reinfuse shed whole blood. These various options may help optimize autologous blood salvage and thereby minimize the likelihood of homologous blood transfusions. Autologous reinfusions eliminate many of the hazards associated with homologous transfusions, ie., the infection transmission, incompatibility reactions, febrile reactions, and limited blood supplies.

In Group 1, we concluded that having to interrupt the collection of shed whole blood from the surgical field was a serious problem. This was due to the lack of feasibility to move the collected blood from the collection cardiotomy reservoir to the reinfusion cardiotomy reservoir. In Group 1, we attempted to transfer collected blood from the collection reservoir to the reinfusion reservoir by eliminating the source suction, thus allowing the collected blood to drop into the infusion cardiotomy via gravity. This left the surgeon temporarily without suction and a blood-filled operative field. A further modification was instituted for Group 2 by adding an additional roller pump between the collection and reinfusion cardiotomy reservoirs, providing flow in the 0-500 ml range. This modification provided the surgeon with uninterrupted suction and allowed the collected shed whole blood to actively pass from collection cardiotomy reservoir to the reinfusion cardiotomy reservoir. Inserting a hemoconcentrator in the recirculation line of the modified RID gives the clinician another alternative to alter the quality of the collected shed blood prior to its reinfusion to the patient.

CONCLUSION:

There are well documented techniques regarding the management of massive blood loss during this type of aortic surgery (4-6). All seem to provide the patient with volume replacement by massive administration of blood products, including autologous blood. The described technique of collecting, ultrafiltrating, processing via cell washing, and autotransfusion of shed whole blood seems to provide safe management of these patients who are at risk for massive blood loss during aortic surgery.

REFERENCES:

1. Roseberg J, Shine T. Thoracic aortic disease. In: Kaplan JA. Cardiac Anesthesia. Orlando: Grune and Stratton. 1987: 732.
2. Svensson LG, Crawford ES, Hess KR, Coselli JS, Safi HJ. Experience with 1509 patients undergoing thoracoabdominal aortic operation. J Vasc Surg. 1993; 17: 357-68
3. Hartz RS, Smith JA, Green D. Autotransfusion after cardiac operation assessment of hemostatic factors. J Thorac Cardiovasc Surg. 1988; 96: 178-182.
4. Dekkers R, Rizzo R, Body S, Fitzgerald D, Cohn L. Shed whole blood autotransfusion during aortic aneurysm op-

eration with a modified collection infusion system. Ann Thorac Surg. 1995; 59: 184-6.
5. Wooten MJ. Use and analysis of saline washed red blood cells. Transfusion. 1976; 16: 464-8.
6. Long GW, Glover JL, Bendick PJ, et al. Cell washing versus immediate reinfusion of intra-operatively shed blood during abdominal aortic aneurysm repair. Am J Surg. 1993; 166: 97-102.
7. Ouriel K, Shortell CK, Green RM, Deweese JA. Intraoperative autotransfusion in aortic surgery. J Vasc Surg. 1994; 18: 16-22.