

## Review

# Intraoperative blood salvage in vascular surgery – worth the effort?

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## Abstract

Intraoperative autologous transfusions have been used for many years to avoid transmission of infections, especially in vascular surgery, where blood usage is considerable. Several autotransfusion devices exist, but these devices are often associated with negative outcomes such as cost, contamination, and removal of essential blood components (e.g. platelets). Preoperative autologous blood donation is another blood preservation method to avoid possible transfusion-related infections. Several vascular surgery groups have compared the use of these techniques, and their results are discussed in this review. Cell saver techniques often do not prevent the need for transfusions, nor are they very cost-effective; therefore, their use should be considered on a case-by-case basis.

**Keywords** autologous, autotransfusion, blood, blood donation, blood preservation, transfusions

Intraoperative autologous transfusions have been used over the past 20 years as a means to avoid giving patients blood products from other individuals because of the risk of transfusion-related infections such as hepatitis and HIV. The incidence of hepatitis B and hepatitis C per unit of blood is estimated at 1 in 220,000 and 1 in 1,600,000, respectively, and the risk for HIV transmission is 1 per 1,800,000 [1]. Many patients, who for religious reasons will not accept banked blood or autologous donated banked blood, may accept the use of autotransfusion devices to restore their blood volume during an operation. The use of intraoperative autotransfusion dates back to the 19th century, when James Blundell reported having reinfused shed blood in 10 female patients who had hemorrhaged following childbirth.

Two broad classes of devices have been developed to facilitate autotransfusion, and a few examples representing each class are listed in Table 1. One type – the red blood cell (RBC) washing type – collects the shed blood, washes and centrifugally separates out the RBCs, and then reinfuses them. RBC washing devices can theoretically remove any toxic byproducts in the scavenged blood; however, they also

remove platelets and clotting factors. The RBC washing devices are of variable capacity and design (e.g. continuous or discontinuous flow) and yield RBC concentrates with different characteristics and quality [2,3]. The second major type of autotransfusion device – hemofiltration only devices – just collects the blood, filters it, and reinfuses it. These devices return all of the blood elements, including the platelets and the clotting factors, but they do not remove potentially harmful debris and contaminants [4].

No clinical sequelae, such as coagulopathy, renal insufficiency, abnormalities of oxygen exchange, or electrolyte disorders, have been recognized with the use of either of these devices. Devices that are capable of washing RBCs are the most costly to set up and operate, but the presence of inflammatory mediators in unwashed blood and their potential to cause unwanted pulmonary and circulatory effects may justify the extra cost of washing RBCs before reinfusion. Economically, the set up for both types of devices has been shown to be cost-effective only when 2 or more units are recovered from the surgical field during the operation and then transfused back into the patient.

**Table 1**

**Examples of autotransfusion devices**

Type of device		Manufacturer
Hemofiltration only	ConstaVac™ Blood Conservation System	Stryker
	Autovac™ Postoperative Orthopaedic Autotransfusion Canister	Boehringer Laboratories
	Solcotrans® Orthopaedic Autotransfusion System	Davol
	AT200™ Hemofiltration System	Hematec
Red blood cell washing	OrthoPAT™	Haemonetics Corp.
	Continuous Autotransfusion System (CATS)	Fresenius AG
	Cell-Saver or Cell Saver 5	Haemonetics Corp.
	Medtronic Autolog or Medtronic Sequestra 1000	Medtronic, Inc.
	Cobe Baylor Rapid Autotransfusion Device (BRAT or BRAT 2)	COBE Cardiovascular

Another method used by many surgeons is to have the patients donate units of their own blood before their operation, thus reducing some of the risks associated with banked blood transfusion. The use of preoperative autologous blood donation (PAD) has been evaluated in some procedures, including elective orthopedic procedures, coronary artery bypass procedures, and radical prostatectomy. It was believed that the use of PAD in these procedures would be cost-effective, but this has not been proven to be true [5–7].

Vascular surgeons have adopted the use of intraoperative autologous transfusions during aortic surgery in addition to PAD [8,9]. Many vascular surgeons believed that utilization of the cell saver devices would obviate the need to transfuse homologous banked blood into these patients, and might be cost-effective. A number of vascular surgery groups have reviewed their experience with these blood administration techniques in those patients undergoing aortic bypass or aortic reconstruction surgery. The studies described below are a mixture of prospective and retrospective evaluations of cell salvage techniques, emphasizing their costs and clinical utility in patients undergoing vascular surgery.

Kelley-Patteson and colleagues [10] reviewed four groups of patients who were undergoing infrarenal aortic bypass to determine the blood loss in each group and how best to administer blood products to these patients. The groups were as follows: group 1, abdominal aortic aneurysm repair with a tube graft (*n* = 21); group 2, abdominal aortic aneurysm repair with a bifemoral or bi-iliac bypass (*n* = 19); group 3, aortofemoral bypass or bi-iliac bypass for occlusive disease with use of the Cell Saver® Autotransfusion Device (Haemonetics Corp., Braintree, MA, USA; *n* = 18); and group 4, aortofemoral or aortoiliac bypass for occlusive disease without use of the Cell Saver (*n* = 18). Groups 1 and 2 had use of the Cell Saver because it was thought that all aneurysm patients would lose more than 2 units of blood. Groups 3 and 4 were randomized as they presented for oper-

ation. The main purpose of the study was to identify those patients who routinely lost less than 2 units of blood, therefore making routine use of the Cell Saver unnecessary.

Prospectively, the following patient data were collected [10]: preoperative hemoglobin, estimated blood loss, Cell Saver return volumes, intraoperative and postoperative homologous blood transfused, postoperative hemoglobin values on the day of surgery and on postoperative days 1 and 4, complications, and duration of hospital stay. Preoperative hemoglobin was similar in all four groups. Surprisingly, estimated blood loss was also similar between groups, but there was broad variation in each group because three patients had an extreme blood loss. In group 1, 48% of the patients had Cell Saver return volumes of less than 500 ml. In group 2, only 16% of the patients had Cell Saver return volumes less than 500 ml. In group 3, 61% of the patients had Cell Saver volumes returned that were less than 500 ml. Charges for the set up of the Cell Saver Autotransfusion Device were US\$475. Set up for the cannister and suction tubing alone was US\$123.

Patients in group 2 had the greatest need for intraoperative homologous blood administration, with nine patients (47%) requiring blood transfusions [10]. Transfusion requirements for the other groups were much lower, with five patients in group 1 (24%), two patients in group 3 (11%), and three patients in group 4 (6%) needing transfusions. Postoperative blood transfusions were not required in group 1, and only three patients required them in group 2. One patient each in groups 3 and 4 required a postoperative blood transfusion. Postoperative hemoglobin of less than 8.0 g/dl was not reported for any patient. Costs calculated for blood transfusions were US\$202.75 for the first unit and US\$154.25 for each additional unit transfused.

No in-hospital deaths occurred in this series [10]. Only one patient in group 3 had a myocardial infarction during the post-

operative period. No problems with coagulopathy occurred in any patient, and no renal or respiratory problems were noted in any group. The duration of stay was 9.2 days for all patients studied, with no differences seen between groups.

Kelley-Patteson and colleagues [10] concluded that routine set up and use of the Cell Saver Autotransfusion Device is not necessary in those patients undergoing any type of elective aortic surgery, whether for occlusive disease or for aneurysmal disease, because the use of homologous blood was not altered. The only purpose that set up of the Cell Saver Autotransfusion Device was thought to serve in these patients was possibly to provide the surgeon with peace of mind in the event of sudden and unforeseen blood loss, such as when the aorta, vena cava, or renal vein is injured.

Over a 3-year period, Ouriel and colleagues [4] studied intraoperative autotransfusion and homologous blood transfusion in 200 patients undergoing aortic reconstructive procedures. A total of 100 patients had blood collected before surgery and were reinfused with unwashed filtered shed blood during the operation (AT group), and 100 patients were administered homologous blood alone (HT group). Clinical, laboratory, and economic parameters were evaluated and compared.

The groups were similar with respect to demographics, type of procedure, baseline laboratory profiles, and comorbid conditions [4]. The amount of blood salvaged and reinfused averaged  $1729 \pm 68$  ml in the AT group. Patients in the AT group received  $0.6 \pm 0.1$  units of homologous blood intraoperatively, as compared with  $3.4 \pm 0.1$  units in the HT group ( $P < 0.001$ ). Ninety-two patients (92%) in the HT group received 1 or more units of homologous blood during their hospitalization, whereas only 34 (34%) of the patients in the AT group received 1 or more units of homologous blood. Morbidity and mortality rates were similar between groups. Duration of stay and cost of hospitalization were similar between groups. No abnormalities in coagulation parameters, renal function, oxygen exchange, or electrolyte disorders were noted in any patient. Circulating platelets were higher in the AT group ( $201 \pm 9 \times 10^3/\text{mm}^3$  versus  $157 \pm 6 \times 10^3/\text{mm}^3$ ;  $P < 0.001$ ). Fibrinogen also was higher in the AT group ( $242 \pm 11$  mg fibrinogen/dl versus  $196 \pm 14$  mg fibrinogen/dl;  $P < 0.01$ ). Hospital costs were compared and no overall differences were seen. The cost of blood products and infusion equipment was lower in the AT group, which resulted in a cost savings of US\$288 per patient ( $P < 0.001$ ).

Ouriel and colleagues [4] found that the use of an autotransfusion device that administers unwashed, filtered blood back to the patients during operation was safe and efficacious, served as an alternative to homologous blood transfusion, and actually diminished the need for additional homologous blood transfusions. Overall, this group of patients lost more blood and received back more than 2 units of salvaged blood, because two thirds of the patients operated upon had

aneurysmal disease. Those investigators felt that autologous transfusion would be advantageous because it limits exposure to homologous blood transfusions. Additionally, they identified a small cost saving, and preservation of platelets and fibrinogen levels in those patients receiving autotransfusion during the operation. None of the patients donated autologous units of blood preoperatively.

Goodnough and colleagues [11] conducted a retrospective review of patients undergoing elective abdominal aortic aneurysm repair to evaluate the cost-effectiveness of intraoperative blood salvage techniques. Blood loss on average was  $1748 \pm 1236$  ml in these 184 consecutive patients, most of whom (165) had an infrarenal repair. The mean Cell Saver volume salvaged and reinfused was  $578 \pm 600$  ml. During their hospitalization, 163 patients received blood products, with all but two receiving RBCs. A total of 128 patients received RBCs during the operation, and 77 patients received RBCs postoperatively. Thirty-two (89%) of the 36 patients who did not receive any Cell Saver blood required transfusions. Of those patients who had Cell Saver blood salvaged (except for those receiving 750–999 ml of Cell Saver blood), a similar percentage (67%) required homologous blood transfusions. Thirty-one (63%) of the 49 patients who had less than 1000 ml estimated blood loss had cell salvage performed, whereas 120 (87%) of 138 patients who had more than 1000 ml estimated blood loss had cell salvage performed. The cost of cell salvage in this series was US\$326  $\pm$  73. Cost savings could only be demonstrated in 22% of the patients who underwent surgery that employed cell salvage techniques.

Those investigators concluded that intraoperative cell salvage was most beneficial for those patients who have intraoperative blood losses of 1000 ml or more and Cell Saver volumes infused of 750 ml or more [11]. These findings are similar to those in knee replacement surgery, hip replacement surgery, and spinal fusion operations.

Huber and colleagues [12] reviewed the medical records of all patients undergoing elective abdominal aortic reconstructions at Shands Hospital at the University of Florida College of Medicine between January 1991 and June 1995. A total of 173 cases were identified and five were excluded (three because complete medical records were not available, and two because massive coagulopathic bleeding occurred during the postoperative period). The Cell Saver Autotransfusion Device was used in 138 of the 168 procedures reviewed.

Estimated blood loss was  $1737 \pm 1299$  ml and the mean volume of blood salvaged by the Cell Saver was  $702 \pm 644$  ml [12]. Estimated blood loss and Cell Saver salvage rates were higher in those patients with aneurysms than in those patients with aortoiliac occlusive disease (estimated blood loss of  $2127 \pm 1467$  ml versus  $1415 \pm 1047$  ml;  $927 \pm 790$  ml versus  $515 \pm 408$  ml Cell

Saver volume returned). Cell Saver blood salvage amounts were 500 ml or greater in 79.4% of aneurysm patients and in 52% of patients with aortoiliac occlusive disease. Predictors of 500 ml Cell Saver salvage returns or greater were as follows: large aneurysms ( $6.79 \pm 1.84$  cm versus  $5.72 \pm 0.71$  cm) and male sex (82.0% versus 46.2%) in patients with aneurysms; and lower preoperative platelet counts ( $262 \pm 93 \times 10^3/\text{mm}^3$  versus  $311 \pm 113 \times 10^3/\text{mm}^3$ ), concomitant renal revascularization (20.5% versus 0%), and prolonged operative time ( $7.9 \pm 2.4$  hours versus  $6.9 \pm 2.1$  hours) in those patients with aortoiliac occlusive disease. Cell salvage returns of 1250 ml or more were relatively uncommon (28.6% in patients with aneurysms versus 5.3% in those with aortoiliac occlusive disease), and predictors were seen only in those patients with aneurysms and included those patients with concomitant vascular procedures (38.8% versus 15.6%) and those patients who required suprarenal clamping (27.8% versus 6.7%).

Even though Cell Saver was used, 73.8% of patients required homologous blood transfusions, with a mean of  $3.0 \pm 3.1$  units being transfused during the hospital stay [12]. No difference was seen in the blood transfusion requirement between patients with aneurysms and those with aortoiliac occlusive disease. The calculated cost for cell salvage return of 1 unit (determined by dividing the cost of the cell salvage set up by the number of units actually salvaged) was US\$128.77 for patients with aneurysms and US\$231.91 for patients with aortoiliac occlusive disease. A potential saving if the cell salvage technique was not used was also calculated: US\$252.80 for patients with aneurysms and US\$352.84 for those with aortoiliac occlusive disease.

Huber and coworkers [12] concluded that the use of cell salvage techniques is not cost-effective during elective aortic reconstruction procedures and should only be used for complex procedures in which considerable blood loss is anticipated. None of the other clinical factors could accurately predict the high volume of blood loss that could be salvaged during the procedure in order to make use of the Cell Saver cost-effective.

That group went on to report an additional study of the use of intraoperative autologous transfusion devices with a decision analysis model [13]. The authors took the transfusion requirements from the previously cited study from either homologous blood transfusions or cell salvage techniques, and then factored in the risk for allogeneic transfusion-related complications (transfusion reaction, hepatitis B, hepatitis C, HIV, human T-cell lymphotropic virus type I and II), along with associated treatment costs (US\$ and quality-adjusted life years [QALYs]). The use of the Cell Saver proved not to be cost-effective in either abdominal aneurysm repair or aortoiliac occlusive disease patients. The cost was increased by US\$263.75 in the aneurysm patients, but only 0.00218 QALYs were added (US\$120 794 per QALY). For aortoiliac

occlusive disease the cost was US\$356.68 and 0.00062 QALYs were added (US\$528 275 per QALY). Cost-effectiveness was achieved only if the incidence of hepatitis C was 10-fold higher and if blood loss routinely was more than 5 units in the aneurysm patients and 6 units in the aortoiliac occlusive disease patients.

## Conclusion

The use of cell salvage techniques in vascular surgery has the potential to prevent the use of homologous blood transfusions, but in reality that does not appear to occur. The risk for transmission of disease by blood transfusions is sufficiently low that the use of the Cell Saver does not appear to have an impact on the individual patient. Cost savings only occur when there is a high blood loss and a high RBC salvage rate. If the surgeon is concerned, the reservoir is the optimal method to use in cases that have the potential for high blood loss, and if excessive blood loss does occur then the cell salvage device can be activated.

## Competing interests

None declared.

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