The influence of autotransfusion on homologous blood requirements during aortic reconstruction[1]

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To evaluate the influence of intraoperative autotransfusion with the Haemonetics Cell Saver on homologous blood requirement during abdominal aortic reconstruction, 707 patients were evaluated retrospectively. The preautotransfusion group consisted of 557 patients who underwent reconstruction for aneurysms or occlusive disease from 1974 to 1978, before the introduction of autotransfusion, whereas the autotransfusion group consisted of 150 patients who underwent similar procedures from 1980 to 1981, after the introduction of autotransfusion. The preautotransfusion patients required a mean total volume of 5.9 units of homologous blood, with 5.0 units given intraoperatively. In comparison, the autotransfusion patients required a mean total volume of only 3.0 units of bank blood, with 1.7 units given intraoperatively (P = 0.000). The autotransfusion group received a mean volume of 1,068 cc of autologous, salvaged blood per operation. The overall incidence of postoperative complications was 19.7% in the preautotransfusion group and 11.4% in the autotransfusion group (P = 0.017). Operative mortality was 5.6% in the preautotransfusion group and 2.7% in the autotransfusion group (P = 0.146). Intraoperative autotransfusion effectively reduces the volume of bank blood required by patients undergoing abdominal aortic reconstruction without a measurable increase in mortality or morbidity.

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The number of cardiovascular and other major surgical procedures performed annually in the United States has placed a substantial demand upon the available reserves of homologous bank blood. In addition, homologous blood transfusion has inherent risks that have been well described.[1-3] Consequently, increasing interest has been gen-

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erated in various autologous blood conservation techniques.[4–7] Controversy still exists, however, concerning whether such methods have been effective in conserving a significant amount of homologous bank blood at the expense of increased postoperative mortality or morbidity.[8,9]

Since May 1979, intraoperative autotransfusion using the Haemonetics Cells Saver system (Haemonetics Corporation, 17 Erie Drive, Natick, MA 01760) has been routinely performed during abdominal aortic operations performed at the Cleveland Clinic. To evaluate the effectiveness and safety of intraoperative autotransfusion with the cell saver in reducing the homologous blood requirement during abdominal aortic reconstruction, patients undergoing these procedures before and after the introduction of routine intraoperative autotransfusion were reviewed retrospectively.

Materials and methods

The records of 707 patients who underwent aortic reconstruction for intact aneurysms, ruptured aneurysms, or aortoiliac occlusive disease were reviewed. The preautotransfusion group consisted of 557 patients whose operations were performed between January 1974 and December 1978, before the introduction of intraoperative autotransfusion. The autotransfusion group consisted of 150 patients undergoing similar procedures between January 1980 and April 1981, a period during which routine intraoperative autotransfusion using the Cell Saver was employed. The volume of homologous bank blood transfused during each operation and the first 48 hours postoperatively was tabulated for both groups. In the autotransfusion group, the volume of homologous blood salvaged and retransfused was also recorded. During this study, nearly all banked blood replacement was in the form of whole blood. Postoperative mortality and incidence of common postoperative complications were determined for both groups. Postoperative mortality was defined as death occurring within the first postoperative month. Postoperative complications such as congestive heart failure, stroke, retroperitoneal bleeding, and wound or graft infection were identified by accepted clinical criteria. Acute renal failure was defined as an elevation of the serum creatinine by 1.0 mg/dl above the preoperative baseline, irrespective of urine volume. Pulmonary insufficiency was distinguished by the need for ventilatory support for longer than 72 hours postoperatively or by the presence of diffuse, bilateral, radiographically seen pulmonary infiltrates in the absence of clinical evidence of congestive heart failure. Myocardial infarction was indicated by acute ST-T wave elevation or the appearance of new Q waves on electrocardiographic examination, supported by appropriate isoenzyme changes. The diagnosis of colonic ischemia was restricted to patients with mucosal or bowel wall ischemia as determined endoscopically or at laparotomy.

There were no meaningful differences in surgical technique between the two groups. Regional heparinization, systemic heparinization, or both were routinely used in each group unless contraindicated.

In both groups, blood was transfused to replace estimated intraoperative losses and to maintain a hematocrit near 30% in the postoperative period. Coagulation factors were transfused to correct abnormal prothrombin time, partial thromboplastin time, and platelet count values if persistent bleeding occurred. Antibiotics were administered throughout the perioperative period in both groups. The introduction of routine preoperative coronary angiography and intraoperative autotransfusion in this subset appears to be the only major difference discernible between the preautotransfusion and the autotransfusion groups.[10] As the result of survey coronary angiography, elective myocardial revascularization was performed before aortic reconstruction in 29% of patients in 1980 and 1981, whereas only 16% of those in the 1974–1978 series had incidentally required previous aortocoronary bypass. Coronary angiography, with or without myocardial revascularization, would not reduce the homologous blood requirement of abdominal aortic reconstruction. Any savings in homologous bank blood requirement between the two groups would only be related to the use of intraoperative autotransfusion.

The results of this investigation were subjected to statistical analysis by the two (independent) sample t tests, the chi-square test, and Fisher's exact test when appropriate. The conclusions were strictly interpreted, relying on the Bonferoni Inequality and the concept of the overall significance level, $\alpha = 0.05$ ($\chi\alpha = 7.89$, d.f. = 1, $P = 0.005$).[11]

Results

The preautotransfusion and the autotransfusion groups were statistically similar in terms of age, sex, and vascular diagnosis. Ruptured aneu-

Table 1. Comparison of preautotransfusion and autotransfusion groups: age, sex, and vascular diagnosis

	Preauto-transfusion group	Auto-transfusion group	P value
	(N = 557)	(N = 150)	
Mean age (years)	62.9	63.7	0.311 (NS)
Sex (%)			
Male	80.8	81.3	0.881 (NS)
Female	19.2	18.7	0.881 (NS)
Diagnosis (%)			
Intact aneurysm	62.9	64.0	0.650 (NS)
Ruptured aneurysm	6.1	2.7	0.098 (NS)
Occlusive disease	31.1	33.3	0.595 (NS)

NS = not significant.

rysms comprised only a small fraction of each group (*Table 1*). There was no statistical difference between the groups with respect to electrocardiographic or historical indicators of coronary artery disease, with the exception that fewer patients in the autotransfusion groups reported normal cardiac history (*Table 2*). The increased frequency of myocardial revascularization in the autotransfusion group reflects the more liberal use of coronary angiography during this era.

Patients in the preautotransfusion group received an average of 5.0 units of homologous bank blood intraoperatively, whereas a mean of 1.7 units was required by patients in the autotransfusion group (*Table 3*). This difference was highly significant ($P = 0.000$). Although the volume of homologous blood used during the first 48 hours after operation was similar for both groups, the total perioperative volume of bank blood required by the autotransfusion group was significantly less ($P = 0.000$). Approximately 1,068 cc of autologous blood was salvaged and autotransfused per operation *(Figure)*.

Postoperative death occurred in 31 (5.6%) of the preautotransfusion patients and in 4 (2.7%) of the autotransfusion patients, a difference that did not achieve statistical significance ($P = 0.146$). Postoperative complications, although strictly defined, were infrequent, with 80.3% of the preautotransfusion patients and 88.6% of the autotransfusion patients experiencing an uncomplicated postoperative course. The incidence of postoperative complications is presented in *Table 4*. Although fewer complications occurred in the autotransfusion group than in the preautotransfusion group in each category, no statistical significance can be attached to these differences.

Table 2. Comparison of preautotransfusion and autotransfusion groups: cardiac history, electrocardiographic diagnosis, and cardiac diagnosis

	Preauto-transfusion group	Auto-transfusion group	P value
	(N = 557)	(N = 150)	
Cardiac History (%)			
Normal	62.1	48.0	0.002 (S)
Myocardial infarction	23.7	26.7	0.452 (NS)
Angina pectoris	15.4	24.0	0.014 (NS)
Congestive heart failure	2.9	3.3	0.7868 (NS)
Myocardial revascularization	15.6	29.3	0.000 (S)
Electrocardiographic diagnosis (%)			
Normal	47.9	48.7	0.874 (NS)
Coronary artery disease	52.1	51.3	0.516 (NS)
Cardiac diagnosis (%)*			
Normal	37.7	31.3	0.150 (NS)
Coronary artery disease	62.3	68.7	0.150 (NS)

* Either abnormal cardiac history or abnormal electrocardiogram.
S = statistically significant, NS = not significant.

Renal failure, pulmonary insufficiency, and myocardial infarction remain the most common postoperative complications, whereas infection, colonic ischemia, and stroke were rare in both groups. It is noteworthy that retroperitoneal bleeding was distinctly uncommon in the autotransfusion group (0.7%).

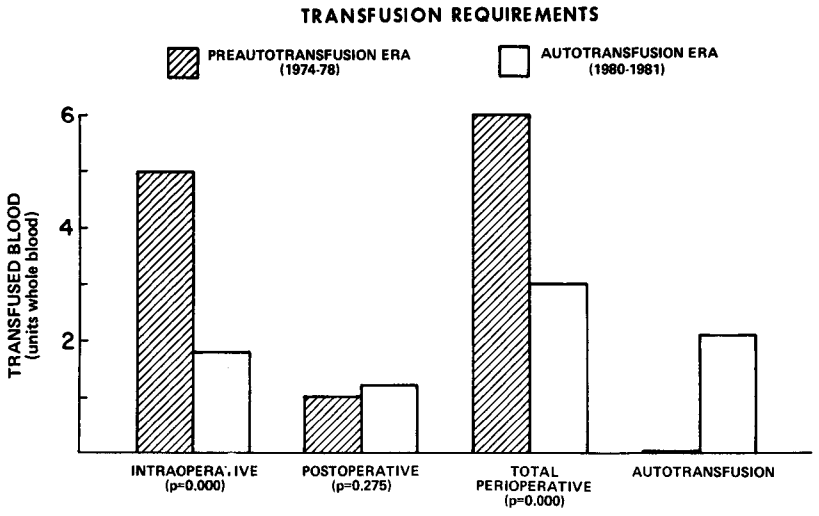
Discussion

Intraoperative blood conservation has several advantages. First, it reduces the inherent risks of

Table 3. Transfusion requirements in the preautotransfusion and the autotransfusion groups.

	Preauto-transfusion group	Auto-transfusion group	P value
	(N = 557)	(N = 150)	
Homologous bank blood Transfused (units)*			
Intraoperatively	5.0	1.7	0.000 (S)
Postoperatively	1.0	1.2	0.275 (NS)
Total	5.9	3.0	0.000 (S)
Autologous blood Autotransfused		1068 cc	

* 1 unit = 450 ± 45 cc.
S = Statistically significant, NS = Not significant.



Graphic comparison of the transfusion requirements of the preautotransfusion and autotransfusion groups

homologous blood transfusions, including incompatibility reactions, isoimmunization, and disease transmission. In addition, autologous blood salvage preserves available bank blood supplies for other uses, such as fractionation for component therapy, treatment of trauma patients, and blood replacement during surgical procedures in which autotransfusion is not feasible. Since cardiovascular surgical procedures frequently involve substantial and predictable blood loss, require heparinization, and are free from bacterial or neoplastic contamination, they are ideally suited to intraoperative autotransfusion. Early reports of autotransfusion indicated an unacceptably high incidence of coagulopathy, renal failure, pulmonary failure, and air embolism.[8,9] However, improvements in the design of autotransfusion equipment have led to the development of the Haemonetics Cell Saver autotransfusion system.[12] Our experience with this system suggests that autologous blood shed at operation may be effectively salvaged with no measurable increase in the mortality or morbidity associated with abdominal aortic reconstruction.

Table 4. Incidence of postoperative complications in the preautotransfusion and autotransfusion groups

Complication	Preauto-transfusion group, %	Auto-transfusion group, %	P value
	(N = 557)	(N = 150)	
Renal failure	7.0	4.0	0.181 (NS)
Pulmonary insufficiency	6.1	3.3	0.187 (NS)
Myocardial infarction	5.2	1.3	0.040 (NS)
Retroperitoneal bleeding	3.8	0.7	1.061 (NS)
Wound infection	2.0	1.3	1.000 (NS)
Colonic ischemia	1.3	0.7	1.000 (NS)
Stroke	1.1	0.0	0.351 (NS)

NS = Not significant.

Approximately 30% of the autotransfusion patients in this study required no homologous blood whatsoever. This finding is consistent with that of Brewster et al,[13] who reported that as many as 50% of similar patients required no bank blood when autotransfusion was employed. Since the mean hematocrit of patients in the autotransfusion group was 33% at the time of their discharge, acceptance of a greater degree of normovolemic anemia would undoubtedly contribute to the reduction in homologous blood use in these patients. It has been reported that hematocrits as low as 25% have been safely tolerated following myocardial procedures if oxygenation is adequate,[4,5] and there may be a theoretical rheologic advantage to decreased blood viscosity in patients with peripheral vascular disease. Intraoperative blood salvage probably represents the major factor responsible for the reduction in homologous transfusion since the savings in bank blood occurs at the time of intraoperative autotransfusion, whereas no significant difference was demonstrated in the homologous blood requirement of our groups during the postoperative period. The volume of salvaged blood in our study is similar to that described in other reports,[13–15] but autotransfusion is not completely efficient because of unavoidable loss of blood in

the sponges and drapes, and by hemolysis. Moreover, the hematocrit of autotransfused blood is lower than that of homologous banked blood.[7] Consequently, adequate bank blood must still be available for aortic reconstruction, as indicated by the mean bank blood requirement (3 units) in the autotransfusion group in this investigation.

The operative mortality was 5.6% in the preautotransfusion group and 2.7% in the autotransfusion group, but this difference was not statistically significant. No deaths were directly attributable to intraoperative autotransfusion. The overall incidence of postoperative complications was reduced from 19.7% in the preautotransfusion group to 11.4% in the autotransfusion group ($P = 0.017$). Although this degree of statistical confirmation ordinarily is convincing, the Bonferoni Inequality analysis of multiple variables was applied because the data in the two groups in this study were collected at different times. With this demanding method, reduction of postoperative complications in the autotransfusion group did not achieve statistical significance. It is also conceivable that improvements in anesthetic management, intraoperative technique, and postoperative care could obscure detrimental effects in the autotransfusion group. This, however, seems unlikely.

With the Bonferoni Inequality principle, improvement in the incidence of postoperative myocardial infarction from 5.2% in 1974–1978 to 1.3% in 1980–1981 was not intepreted as significant ($P = 0.04$). We suspect, however, that other, often unrelated, variables did not measurably alter the cardiac risk of our patients from 1978–1980. We are convinced that survey coronary angiography and, in selected patients, preliminary myocardial revascularization have provided patients who had severe coronary artery disease with considerable protection during aortic reconstruction.

The incidence of postoperative renal failure and pulmonary insufficiency was not significantly different in the autotransfusion group. Although previous reports have demonstrated significant reduction in the microaggregate levels of autotransfused blood, suggesting a theoretical advantage in preventing pulmonary insufficiency, the clinical significance of the observation remains speculative.[7,16] The apparent reduction in the incidence of pulmonary insufficiency in our autotransfusion group did not achieve statistical significance, perhaps because of the use of efficient blood filters at this institution from 1974 through 1978.[17]

The low incidence of postoperative retroperitoneal bleeding and the comparable postoperative transfusion requirements in both groups indicate that autotransfusion did not cause significant coagulopathy at the volumes used in this study. Although transient abnormalities in prothrombin time, partial thromboplastin time, and platelet determinations occur with autotransfusion, they tend to resolve by the seventh postoperative day.[7,13] It is possible that heparin priming solution may be autotransfused with salvaged blood from the cell saver device. Accordingly, adequate reversal of heparin effects with protamine sulfate should be performed at the time of abdominal closure. The safe maximum volume of autotransfusion is unknown.[13,14,18] Since autotransfused blood consists of washed, packed red blood cells suspended in saline and is nearly devoid of coagulation factors, close monitoring and replenishment of coagulation factors with fresh frozen plasma and platelet transfusions are necessary when large volumes of autotransfused blood are required.[7,13] In this series, approximately one third of the autotransfusion group required fresh frozen plasma, but platelet transfusions were rarely indicated.

Considering the results of this investigation, we believe that intraoperative autotransfusion with the use of the Haemonetics Cell Saver system has proved to be an efficient and safe method for reducing the volume of homologous bank blood required by patients undergoing abdominal aortic reconstruction at the Cleveland Clinic. Conservation of 2 to 3 units of blood per operation has been attained in these patients without a measurable increase in the incidence of postoperative mortality or morbidity.

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References

1. Diehl JT, Cali RF, Hertzer NR, Beven EG. Complications of abdominal aortic reconstruction. An analysis of perioperative risk factors in 557 patients. Ann Surg 1983; **197**:49–56.
2. Myhre BA. Fatalities from blood transfusion. JAMA 1980; **244**:1333–1335.
3. Weisel RD, Dennis RC, Manny J, Mannick JA, Valeri CR,

Hechtman HB. Adverse effects of transfusion therapy during abdominal aortic aneurysectomy. Surgery 1978; **83**:682–690.
4. Cordell AR, Lavender SW. An appraisal of blood salvage techniques in vascular and cardiac operations. Ann Thorac Surg 1981; **31**:421–425.
5. Cosgrove DM, Thurer RL, Lytle BW, Gill CG, Peter M, Loop FD. Blood conservation during myocardial revascularization. Ann Thorac Surg 1979; **28**:184–189.
6. Krämer AH, Hertzer NR, Beven EG. Intraoperative hemodilution during elective vascular reconstruction. Surg Gynecol Obstet 1979; **149**:831–836.
7. O'Hara PJ, Hertzer NR, Santilli PH, Beven EG. Intraoperative autotransfusion during abdominal aortic reconstruction. Am J Surg 1983; **145**:215–220.
8. Duncan SE, Edwards WH, Dale WA. Caution regarding autotransfusion. Surgery 1974; **76**:1024–1030.
9. Rakower SR, Worth MH Jr, Lackner H. Massive intraoperative autotransfusion of blood. Surg Gynecol Obstet 1973; **137**:633–636.
10. Hertzer NR, Young JR, Kramer JR, et al. Routine coronary angiography prior to elective aortic reconstruction. Results of selective myocardial revascularization in patients with peripheral vascular disease. Arch Surg 1979; **114**:1336–1344.
11. Miller RG Jr. Simultaneous statistical inference. New York, McGraw-Hill, 1966.
12. Orr M. Autotransfusion: the use of washed red cells as an adjunct to component therapy. Surgery 1978; **84**:728–730.
13. Brewster DC, Ambrosino JJ, Darling RC, et al. Intraoperative autotransfusion in major vascular surgery. Am J Surg 1979; **137**:507–513.
14. Brener BJ, Raines JK, Darling RC. Intraoperative autotransfusion in abdominal aortic resections. Arch Surg 1973; **107**:78–84.
15. Thomas GI, Jones TW, Stavney LS, Manhas DR, Carson SAA. Experiences with autotransfusion during abdominal aortic aneurysm resection. Am J Surg 1980; **139**:628–633.
16. Bennett SH, Geelhoed GW, Terrill RE, Hoye RC. Pulmonary effects of autotransfused blood. A comparison of fresh autologous and stored blood with blood retrieved from the pleural cavity in an in situ lung perfusion model. Am J Surg 1973, **125**:696–702.
17. Reul GJ Jr, Beall AC Jr, Greenberg SD. Protection of the pulmonary microvasculature by fine screen blood filtration. Chest 1974; **66**:4–9.
18. Wright CB, Geelhoed GW, Mason KG. Autotransfusion in the subhuman primate. Am J Surg 1974; **128**:49–53.