Intraoperative cell salvage in ruptured abdominal aortic aneurysms

U. M. BRACALE [1], L. DEL GUERCIO [2], G. CORTE [1], F. DAVIDE [2], F. PECORARO [1], M. PORCELLINI [2], G. BAJARDI [1], G. BRACALE [2]

[1] *Vascular Surgery, University of Palermo Palermo, Italy*
[2] *Vascular Surgery, Federico II University Naples, Italy*

Aim. **The aim of this study was to evaluate the impact of intraoperative cell salvage (ICS) on the early outcome after open repair (OR) of ruptured abdominal aortic aneurysm (rAAA).**

Methods. **This is a retrospective review of 73 consecutive patients who underwent emergency OR of infrarenal rAAA with ICS between 2005 and 2008 (Group I), compared to 51 repairs from 2002-2004 with no ICS (Group II). In addition, transfusion protocol of platelets and fresh frozen plasma (FFP) administration on admission and during surgery was adopted in patients in Group I to maintain coagulation competence.**

Results. **ICS reduced bank blood demand by 63.6% (from 11 to 4 units, P<0.001) compared to controls, and had a strong impact on rates of postoperative complications (P=0.05), or death (43.8% *vs.* 52.9%, P<0.05) or in-hospital LOS (P<0.07) in these patients. Patients surviving in Group I had significantly higher postoperative haemoglobin level (11.5 *vs.* 9.6 g/dL, P<0.05) and platelet count (267 *vs.* 95 x 10^9 L, P<0.001), a shorter APTT (31 s *vs.* 47 s, P<0.05) and a lower INR (1.3 vs. 2.1, P<0.01) than patients who died postoperatively. ICS volume was significantly higher in patients with suprarenal aortic clamping and in those who had bifurcated grafting reconstruction (P<0.05), but amount of red blood cells (RBC) collected did not influence outcome.**

Conclusion. **These results suggest that intraoperative cell salvage, minimizing perioperative homologous blood transfusion, is an important determinant of outcome after rAAA repair. Combined administration of balanced blood components may contribute to improve the survival of the patients.**

KEY WORDS: Aneurysm, ruptured - Surgical procedures, operative - Blood platelets - Plasma - Treatment outcome.

Despite the increasing use of emergency endovascular repair (eEVAR) of ruptured abdominal aortic aneurysm (rAAA) in selected patients with suitable anatomy is associated with a lower overall in-hospital mortality,[1, 2] open surgical repair (OR) remains the gold standard for patients with hemodynamic instability.[3, 4]

Factors affecting mortality rates after rAAA open repair include advanced age, female gender and other comorbidities, such as preoperative renal insufficiency, chronic obstructive pulmonary disease, preoperative shock, and institutional and surgeon volumes.[1-6]

In addition, loss of consciousness and haemoglobin level has been reported to predict outcome.[7] Because OR for rAAA is associated with significant blood loss, the patients have large homologous blood transfusion requirements[8], causing transfusion reac-

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Corresponding author: U. M. Bracale, Department of Vascular and Endovascular Surgery, University of Palermo, 90127 Palermo, Italy. E-mail: umbracale@unipa.it

TABLE I.—*Comparison of the two groups.*

	Group I (73 patients)	Group II (51 patients)	P value
Age (yrs.)	72 (57-89)	73 (60-87)	NS
Men	98.1%	96.1%	NS
Median preoperative systolic blood pressure (mm Hg)	93.5	95.7	NS
Median preoperative haemoglobin (g/dL)	8.6 (4.5-11.9)	8.3 (5.0-11.1)	NS
Median preoperative platelet count (x10⁹/L)	177 (112-295)	183 (98-327)	NS
Median preoperative APTT (s)	48 (31-93)	43 (28-112)	NS
Median preoperative INR	1.2 (0.9-1.8)	1.4 (1.0-2.3)	NS
Suprarenal clamping	67.1%	56.9%	NS
Cross-clamping time (min)	39.5 (19-115)	37.8 (28-87)	NS
Aortoaortic tube grafting	47.9%	41.2%	NS
Median intraoperative blood loss (mL)	1757 (723-3135)	1825 (987- 3674)	NS
Homologous RBC transfusion (units)	4 (2-7)	11 (5-18)	<0.001
Platelets transfusion (units)	5 (3-9)	1.3 (1-3)	0.005
FFP transfusion (units)	5 (3-8)	1.8 (1-4)	0.006
Median postoperative haemoglobin (g/dL)	10.3(8.1-12.2)	10.5 (7.9-11.4)	NS
Median postoperative platelet count (x10⁹/L)	219 (115-325)	165 (47-231)	<0.001
Median postoperative APTT (s)	37 (24-75)	63(41-131)	<0.001
Median postoperative INR	1.7 (0.8-2.5)	2.4 (1.5-4.6)	<0.01
Median postoperative blood loss (mL)	245 (87-552)	525 (258-1737)	0.01
Postoperative complications (all)	59%	77%	0.05
Reoperation for intraabdominal bleeding	—	5.8%	—
Mortality	43.8%	52.9%	<0.05
Median ICU stay	2.8 (1-9)	4.1 (1-13)	0.05
Median length of hospital stay (days)	10.3 (1-34)	12.7 (3-45)	<0.07

NS: not significant.

tions, immunosuppression, higher postoperative infection rates and increased mortality.[9] There are a number of studies and RCTs reporting the use of intraoperative cell salvage (ICS) in elective abdominal aortic aneurysm surgery;[10-12] on the contrary, there is little published data on ICS during rAAA repair, so that its use remain controversial.[13] We present the combined experience of two Italian Vascular Surgery canters with this autologous transfusion technique in rAAA open repair.

Materials and methods

Between 2005 and 2008, 73 patients (Group I) underwent OR for infrarenal rAAA at two Vascular Surgery Centers (University of Palermo and University of Naples) using ICS. This series was compared with 51 repairs (Group II) from 2002-2004 with no ICS (Table I).

In Group I patients, 68 (98.1%) were males and 5 (1.9%) females with a median age of 72 years (57-89 years). A contrast-enhanced spiral CT 5-mm slices of abdomen was performed in 67 patients (91.8%). Of these, 39 were transferred from other hospitals with CT scan. Color-Duplex scan was performed in the operating theatre in the remaining six patients (8.2%). Forty-five (61.6%) patients were submitted to OR because of hemodynamic instability (systolic pressure <70 mmHg). The remaining 28 patients were judged unsuitable for eEVAR. Eleven of them had short proximal neck, 4 presented with an aorto-iliac aneurysm to both iliac bifurcations (type D aneurysm), 4 were excluded because of insufficient access and 9 were not treated by EVAR due to unavailability of adequate endograft. Median haemoglobin concentration on admission was 8.6 g/dL (4.5 to 11.9 g/dL), platelet count was 177 x 10^9 L (112 to 295 x10^9 L), APTT was 48 s (31 to 93 s), and INR was 1.2 (0.9-1.8). All patients were

rated on general anaesthesia via a midline abninal incision.

n patients in Group I the transfusion strategy luded administration of platelets and fresh frozen sma (FFP) together with red blood cells (RBC) on nission and continued throughout surgery, while the trol group received platelets and FFP transfusion en abnormalities in coagulation parameters were ed, according to that time existing guidelines.[14]

Blood lost during surgery was collected with an otransfusion system (Dideco Electa, Sorin Group, y), washed, and reinfused within 6 h of collection, ording to the manufacture's protocol.[15] Homolos blood was administered when the haemoglobin ncentration fell below 8 g/dL, or when ischemic ctrocardiographic changes persisted after correcn of hypovolemia, and salvaged RBC were unalable. A retrospective study was done analyzing operative haemoglobin level, platelet count, acte partial thromboplastin time (APTT), internanal normal ratio (INR), intraoperative and postrative blood losses, volume of autologous RBC vaged and reinfused, number of packed homolos RBC transfusion, amount of platelets and FFP nsfusion, perioperative laboratory parameters, idence of postoperative complications, length of y (LOS) in the intensive care unit (ICU) and in spital, and in-hospital mortality. Intraoperative od loss was quantified by measuring the volume the salvaged RBC and weighing all blood-soaked aratomy sponges; postoperative blood loss was imated from the quantity of blood collected in sed suction drains at 1 day after surgery.

tistical analysis

Data are presented as median and range or frency (%). Results were compared using the χ^2 t, the Student's t-test and analysis of variance NOVA). A P-value <0.05 was considered statistilly significant.

Results

In Group I, supraceliac clamping was necessary in patients (67.1%) with no visceral artery reconstrucn performed. In the remaining 24 patients (32.9%) standard infrarenal clamp was placed. The median mping time was 41.2 min (19 to 115 min) in the supraceliac group *versus* 37.3 min (23 to 78) of the infrarenal group. Dacron tube graft was used in 35 patients (47.9%), while Dacron bifurcated grafts were anastomosed to common iliac arteries in 33 patients (45.2%) and to common femoral arteries in 5 patients (6.8%).

The median RBC volume collected with an hematocrit of 58% (52-63%) from each patient during intraoperative cell salvage was 1102 mL (300 to 2 850 mL); the median homologous RBC transfusion requirement was 4 units (2 to 7 units); 5 (3 to 9 units) of platelets and 5 units (3 to 8 units) of FFP were also administered. The ICS volume was significantly higher with supraceliac clamping than with infrarenal clamping (1 205 mL *vs.* 930 mL, P<0.05), and in patients who had bifurcated graft reconstruction than the patients who had tubular graft (1 178 mL *vs.* 985 mL, P<0.05). After 6 h of intensive care unit stay, the median haemoglobin concentration was 10.3 g/dL (8.1 to 12.2 g/dL), platelet count was 219 x 10^9/L (115 to 325 x 10^9/L), APTT was 37 s (24 to 75 s) and INR was 1.7 (0.8-2.5). Baseline, intra- and postoperative variables, laboratory findings, and outcomes between both the two groups are listed in Table I.

The in-hospital mortality was significantly lower in patients in Group I compared to that of the control group (43.8% *vs.* 52.9%, P<0.05). Three (5.8%) patients in Group II required reoperation for intraabdominal bleeding (mortality 66.6%); no further surgery for postoperative hemorrhage was needed in patients in Group I.

In Group I, the median patients' age was 72 years (57 to 81 years) in patients who survived *versus* 77 years (65 to 89 years) in those who died postoperatively (P<0.01) (Table II). The median preoperative haemoglobin concentration did influence survival (died postoperatively 8.7 g/dL *vs.* lived 10.8 g/dL; P<0.001), The median aortic clamping time and duration of surgery was lower in survivors than in patients who died postoperatively (37 *vs.* 51 min, P<0.01, and 163 *vs.* 185 min, P<0.05, respectively). Median intraoperative arterial systolic pressure was 72 mmHg in patients who died during the operation, 96 mmHg in patients who died postoperatively, and 115 mmHg in patient who survived the treatment (P=0.01). There were not significant differences in amount of RBC collected between patients who died intraoperatively (1 150 mL) or postoperatively (1 290 mL) compared with 1 133 mL in survivors; on the contrary, the number of packed homologous RBC transfusion significantly influenced survival (5, 3 and 2.2 units, re-

TABLE II.—*Laboratory, intra- and perioperative predictors of survival in 73 patients operated for rAAA with use of intraoperative cell salvage and early administration of platelets and plasma.*

	Survivors (56.2%)	Died intraoperatively (6.8%)	Died post-operatively (3.7%)	P value
Age (yrs)	72	78.3	77	<0.01
Median preoperative haemoglobin concentration (g/dL)	10.8	5.6	8.7	<0.001
Median preoperative platelet count (x10⁹/L)	137	—	95	<0.05
Median preoperative APTT (s)	46	—	57	0.05
Median preoperative INR	1.4	—	1.7	NS
Median aortic clamping time (min)	37	28	51	<0.01
Median intraoperative systolic pressure (mmHg)	115	72	96	0.01
Median intraoperative blood loss (mL)	1570	2135	1857	<0.05
Median intraoperative cell salvage (mL)	1113	1150	1290	NS
Median homologous RBC transfusion (units)	2.2	5	3	0.01
Median duration of surgery (min)	163	—	185	<0.05
Median postoperative haemoglobin concentration (g/dL)	11.5	—	9.6	<0.05
Median postoperative platelet count (x10⁹/L)	267	—	95	<0.001
Median postoperative APTT (s)	31	—	47	<0.05
Median postoperative INR	1.3	—	2.1	<0.01
Median postoperative blood loss (mL)	135	—	486	<0.001

* Survivors *vs.* died postoperatively; NS: not significant.

spectively, P=0.01). Patients surviving in Group I had a higher postoperative haemoglobin concentration (11.5 *vs.* 9.6 g/dL, P<0.05) and platelet count (267 *vs.* 95 x 10^9 L, P<0.001), a shorter APTT (31 s *vs.* 47 s, P<0.05), and a lower INR (1.3 *vs.* 2.1, P<0.01) than non-survivors (Table II).

The median LOS in ICU was 2.8 days (1-9 days) for patients in Group I and 4.1 (1-13 days) in Group II (P=0.05) Median LOS in hospital was 10.3 days (1-34 days) for ICS patients and 12.7(3-45) days for control patients (P<0.07).

Discussion

Technological advances in intraoperative cell salvage had expanded its use in a variety of major operations, including aortic reconstruction.[16] In our series of patients undergoing rAAA open repair this autotransfusion method salvaged a median RBC volume of 1 102 mL (300 to 2 850 mL) with no adverse events and resulted in a 63.6% decrease in bank blood usage compared to controls (from 11 to 4 units, P<0.001).

Some studies have investigated ICS in rAAA patients. Marty-Ane *et al.* reported a lower postoperative mortality rate in patients with rAAA treated by ICS compared to patients receiving homologous transfusion (20% *vs.* 52.4%, P=0.029).[10]

A prospective study of 63 patients undergoing OR of rAAA with ICS, compared to 117 retrospective repairs with no blood loss salvage, showed improved survival (in-hospital mortality: 35% *vs.* 57%, P=0.005), by reducing the median intraoperative homologous blood transfusion (P<0.05).[17]

Autotransfusion with a cell saver device is even efficient in patients of the Jehovah's Witness faith who refuse any homologous blood transfusion.[18] Conversely, the incidence of postoperative respiratory and renal complications was more frequent in patients receiving a cell saver volume of ≥3 000 mL.[19]

Furthermore, ours patients who died postoperatively were older (P<0.01), and the duration of surgical repair was lower in survivors (P<0.05). These results support findings from other investigations showing that a short operative time combined with minimizing intraoperative blood loss and homologous transfusion requirements improve survival, especially in the elderly.[8, 19]

A recent work confirmed that the ICS use is most valuable in urgent situations with high blood losses, such rAAA, for which only small amounts of homologous blood were initially available.[20]

In patients presenting with massive bleeding, the

rly administration of platelets and FFP are needed maintain an appropriate haemostasis, with a perierative and a 30-day mortality rates lower than in control patients (24% and 36% *vs.* 56%, P<0.01 d P=0.02, respectively).[21]

Patients in Group I received in addition to ICS more tlets and FPP units and had a significantly higher tlet count, a shorter APTT and a lower INR dur the early ICU stay compared to the control pants, with lower postoperative blood loss (P=0.01) d no relaparotomy for intraabdominal bleeding, and horter in-hospital LOS (P<0.07). In-hospital mority was also significantly lower in these patients mpared to controls without the combined ICS and lanced blood transfusion strategy (P<0.05).

The influence of type of reconstructive procedure is ntroversial. The best outcome was found in patients th repair by a tube graft;[10] accordingly, in our series raoperative RBC salvage volume was significantly ver in patients who had tubular graft replacement n the patients who had bifurcated graft (985 mL *vs.* 78 mL, P=0.05). On the contrary, Posacioglu *et al.* orted a higher need of postoperative blood units in ients who had tubular graft replacement.[13]

Our findings confirmed safety and effectiveness of S in rAAA repair, but with no influence of volume RBC salvaged on patient's outcomes. Undoubtly, patients' age and comorbidities [5] are predicfactors of the operative risk of these patients, but data suggest that preoperative haemoglobin level 0.8 g/dL and number of packed homologous RBC units are more important factors associated with reased mortality. Conversely, the administration of anced blood components appears to be associated h maintenance of haemostatic competence, result in improved survival in patients after rAAA repair.

nitations of the study

The retrospective nature is a limitation of this alysis. However, our study provides further evice that intraoperative cell salvage associated h an early administration of platelets and FPP is useful method during open repair of rAAA, and nificantly reduces homologous blood demand.

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