Original Article

Cardiotomy Suction Versus Red Cell Spinning During Repair of Descending Thoracic Aortic Aneurysms

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ABSTRACT

Two consecutive series of patients undergoing repair of descending thoracic and thoracoabdominal aortic aneurysms with partial cardiopulmonary bypass and low systemic heparinization (activated coagulation time: ACT > 180 sec) for proximal unloading and distal protection were analyzed. During the surgical procedures, thoracic shed blood was recovered either with a red cell spinning autotransfusion device (n=10) or two pump suckers and Duraflo II heparin surface coated cardiotomy reservoirs (n=10). There were 5/10 acute lesions and 1/10 ruptures for the autotransfusion group versus 5/10 acute lesions and 2/10 ruptures for the cardiotomy group (NS). Extension of aortic resection (range 1-8) was 3.6±1.2 for autotransfusion versus 3.5±1.4 for cardiotomy suction (NS). Mean number of reimplanted patches for intercostal and visceral reperfusion was 0.3±0.6 for autotransfusion versus 0.6±1.0 for cardiotomy (NS). Perfusion time was 41±17 min for autotransfusion versus 60±19 min for cardiotomy ($p<0.05$) and cross clamp time was 33±14 min for autotransfusion versus 43±17 min for cardiotomy ($p<0.01$). Total heparin dose was for 9500±2100 IU for autotransfusion versus 9800±1300 IU for cardiotomy (NS). The mean of the lowest ACTs measured during perfusion was 281±121 sec for autotransfusion versus 258±58 sec for cardiotomy (NS). The total protamine dose given was 7800±2100 IU for autotransfusion versus 9700±1900 IU for cardiotomy ($p<0.05$). The volume of washed red cells prepared was 3186±1318 ml for autotransfusion versus 0 for cardiotomy ($p<0.05$). Homologous blood and blood products transfused accounted for 3556±2491 ml for autotransfusion versus 3202±1084 for cardiotomy (NS). Chest tube drainage (day 1) was 878±421 ml for autotransfusion versus 690±520 ml for cardiotomy (NS). Survival (30 days) was 10/10 for autotrans versus 10/10 for cardiotomy (NS). Cardiotomy suction using heparin coated reservoirs for shed blood recovery during partial cardiopulmonary bypass with low systemic heparinization simplified repair of more complex descending thoracic aortic aneurysms and resulted in similar outcome.

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INTRODUCTION

Repair of descending thoracic and thoracoabdominal aortic aneurysms remains a challenging procedure. This is not only due to the technical problems that may occur during surgery of such lesions but also due to the constant threat of distal hypoperfusion, including paraparesis or paraplegia. The latter is, in general, a result of temporary or permanent spinal chord ischemia. Numerous techniques to improve surgical outcome have been developed including simple aortic cross clamping and rapid reanastomosis (1, 2), proximal unloading and distal perfusion with passive shunts (3, 4), staged crossclamping of the aorta (5), and distal perfusion with isolated pumps (6) or partial cardiopulmonary bypass (7).

More recently, heparin coated perfusion equipment in conjunction with low systemic heparinization was introduced into clinical practice. Left heart bypass with roller or centrifugal pumps and heparin coated disposables (8) led to partial cardiopulmonary bypass with low systemic heparinization and improved hemostasis (9). However, during these procedures, shed blood recovery was still performed with red cell spinning devices and therefore the shed blood handling capacity was somewhat limited by the processing speed of the devices used.

The advent of cardiotomy reservoirs with improved thromboresistance (10) allows now for continuous direct reinfusion of large quantities of filtered blood into the venous reservoir despite perfusion with low systemic heparinization. The present study was designed to identify potential drawbacks of this technique.

MATERIALS AND METHODS

Two consecutive series of ten patients undergoing repair of descending thoracic and thoracoabdominal aortic aneurysms (see Figure 1) with proximal unloading and distal perfusion using heparin coated perfusion equipment and low systemic heparinization were analyzed. Thoracic shed blood was recovered either with a red cell spinning device (group autotrans) or two heparinized pump suckers and a heparin coated cardiotomy reservoir (group cardiotomy). Basic patient data for the two analyzed groups is given in Table 1.

SURGERY

All patients operated upon had proximal unloading and distal perfusion with partial cardiopulmonary bypass established before aortic crossclamping. For distal veno-arterial vascular access the left external iliac artery was cannulated and a long flexible venous cannula was directed to the inferior

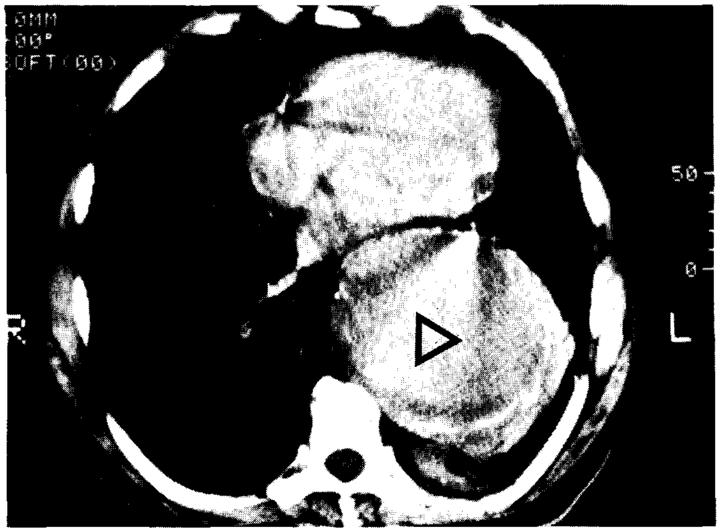

Figure 1
CT-scan: mid chest transverse section of a huge thoracoabdominal aortic aneurysm with a luminal diameter of 12.5 cm. Large blood handling capacities are a prime condition for repair of such lesions.

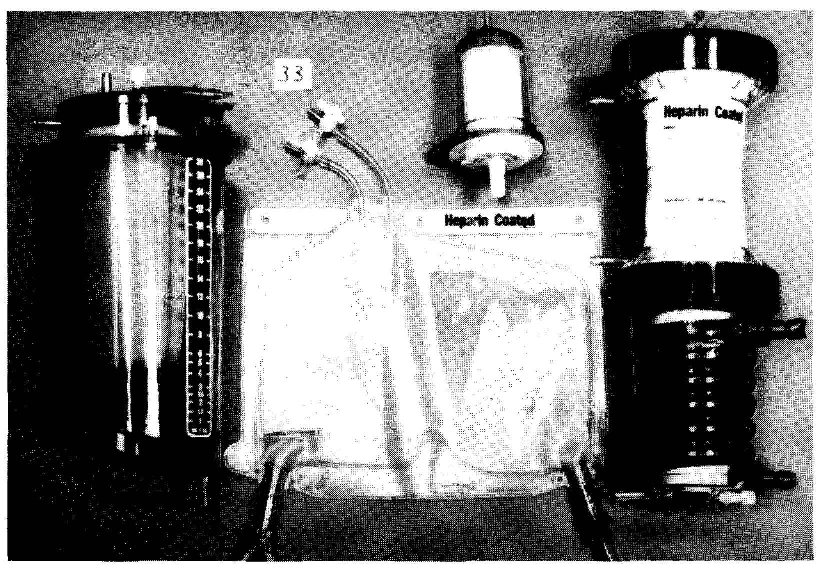

Figure 2
Key elements of a heparin coated cardiopulmonary bypass set used for proximal unloading and distal protection during repair of a descending thoracic aortic aneurysm with low systemic heparinization. The carefully rinsed cardiotomy reservoir, venous reservoir, heat exchanger/oxygenator structure and arterial filter are free of macroscopic clots.

Table 1
Basic data for patients operated upon with partial cardiopulmonary bypass using heparin coated perfusion equipment with low systemic heparinization

Thoracic shed blood recovery	Group Autotrans	Group Cardiotomy	P
Age (years)	58±13	64±7	NS
Males	9/10 (90%)	8/10 (80%)	NS
Acute aneurysms	5/10 (50%)	5/10 (50%)	NS
Ruptured aneurysms	1/10 (10%)	2/10 (20%)	NS
Aortic dissection	3/10 (30%)	5/10 (50%)	NS
True aneurysm	6/10 (60%)	5/10 (50%)	NS
False aneurysm	1/10 (10%)	0/10 (0%)	NS
Aorto bronchial fistula	0/10 (0%)	1/10 (10%)	NS

Table 2
Surgical data for patients operated upon with partial cardiopulmonary bypass using heparin coated perfusion equipment with low systemic heparinization

Thoracic shed blood recovery	Group Autotrans	Group Cardiotomy	P
Resected segments (range 1-8; see ref. 9)	3.6±1.2	3.5±1.4	NS
Thoracoabdominal repair	6/10 (60%)	6/10 (60%)	NS
Intercostal/visceral patch reimplantation	0.3±0.6	0.6±1.0	NS
Crossclamp time (min)	33±14	43±17	0.01
Perfusion time (min)	41±17	60±19	0.05
Pump flow (L/min)	2.1±0.6	2.1±0.6	NS

vena cava through the left external iliac vein. In cases with difficult insertion of the venous cannula through the left external iliac vein, a cannulation technique over a flexible guide wire was used. After cannulation, both the venous and the arterial cannulas were vented into the venous line before perfusion was started.

Staged segmental repair (5) of the descending thoracic or thoracoabdominal aorta was performed beginning proximally and replacing the aortic clamps distal to the established anastomoses. Reimplantation of large intercostal arteries was routine as well as reimplantation of renal and visceral branches for thoracoabdominal aortic aneurysms. To avoid stagnation of blood in the cardiopulmonary bypass system, recirculation through a shunt in the operating field was started immediately after weaning. Graft inclusion was used systematically. If necessary a piece of glutaraldehyde preserved equine pericardium[a] was implanted for this purpose (11).

PERFUSION

Partial cardiopulmonary bypass was accomplished with Duraflo II heparin coated perfusion equipment[b] and low systemic heparinization. A heparin[c] loading dose of 100 IU/kg body weight as well as a heparin priming dose of 1000 IU/L priming fluid was used. Approximately 2000 ml of crystalloids were necessary to prime the heparin coated tubing set including a coated flexible venous reservoir (BRM 1900)[b], a coated heat-exchanger/oxygenator structure (BOS CM50)[b] and a coated arterial filter (AF1040 D)[b] as well as coated cannulas and coated connectors. Partial cardiopulmonary bypass was started with a pump flow corresponding to 50% of cardiac output as determined by thermodilution and adapted after aortic crossclamping to maintain the proximal perfusion pressure above 60 mmHg and similar distal values. During perfusion, the activated coagulation time (ACT)[d] was maintained above the target ACT of 180 sec with additional heparin doses. Thoracic shed blood was recovered either with a red cell spinning autotransfusion device and the usual continuous heparin drip into the suction line (group autotrans) or two roller pump suckers and Duraflo II heparin coated aspirators, heparin coated suction lines and a heparin coated cardiotomy reservoir (10). Hence, in the latter group (group cardiotomy) all blood handling equipment, including that for shed blood recovery, was heparin surface coated. Following perfu-

a Xenomedica SA, Baxter Edwards, Lucerne, Switzerland
b Baxter Bentley, Irvine, CA 92714
c Liquemin Roche, Basel, Switzerland
d Hemochron International Technidyne, Edison NJ 08820

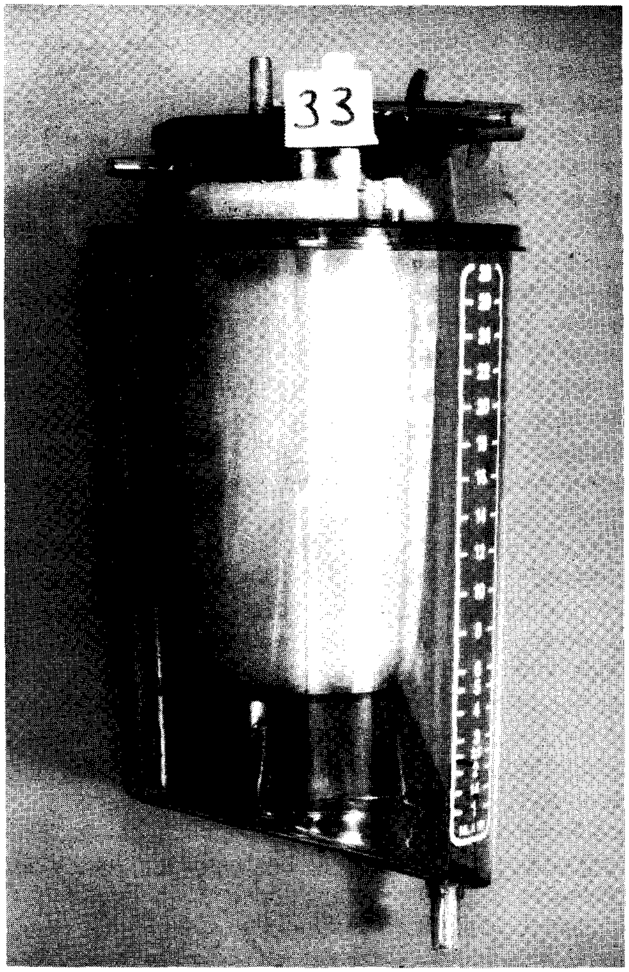

Figure 3
View of the heparin coated cardiotomy reservoir used with low systemic heparinization. The transparent outer hard shell is free of macroscopic deposits (same case as Fig. 2).

sion, protamine was given equivalent to the heparin loading dose. Further protamine was titrated according to ACT values.

Oxygenator sump blood was retransfused immediately after weaning from cardiopulmonary bypass. Thereafter, the perfusion circuit was filled with Ringers Lactate. After the procedure all perfusion sets were carefully analyzed.

DATA ANALYSES

Quantitative data are represented as mean ± the standard deviation. Comparison of quantitative data was made using the Student's t-test for paired or unpaired variables where applicable. Univariate analysis of descriptive data was performed using Fisher's exact test. Statistical significance was confirmed by the probability value ($p<0.05$).

RESULTS

The mean number of aortic segments resected between proximal to the left carotid artery (9) and the aortic bifurcation (range 1-8 aortic segments: 1 arch segment, three thoracic aortic segments, three abdominal aortic segments, 1 aortic bifurcation segment) was 3.6±1.2 for autotrans as compared to 3.5±1.4 for cardiotomy (NS). Although, the proportion of thoraco-abdominal repairs crossing the diaphragm and the respective aortic segments (Table 2) was similar for the two groups (60%) there were more reimplantations of intercostal and/or visceral and renal patches performed in the group cardiotomy. The perfusion parameters are also summarized in Table 2 and show that the aortic crossclamp time was significantly longer in the group cardiotomy as well as the duration of partial cardiopulmonary bypass. The total heparin dose given per patient was 9.5±2.1 10^3 IU for autotrans versus 9.8±1.3 10^3 IU for cardiotomy (NS). For this heparin load, the lowest ACT observed during the perfusion procedures was 183 sec for autotrans versus 175 sec for cardiotomy. The mean values of the lowest ACT per group were however 281±121 sec for autotrans versus 258±58 sec for cardiotomy (NS). The total protamine dose given was equivalent to 7.8±2.1 10^3 IU for autotrans versus 9.7±1.9 10^3 IU ($p<0.05$). The total amount of red cells concentrated and retransfused to the patient was 3186±1318 ml for the group autotrans whereas 0 ml of spun red cells were autotransfused in the group cardiotomy ($p<0.05$). The total amount of homologous blood and blood products including concentrated red cells, fresh frozen plasma, platelet concentrates and coagulation factors accounted for 3556±2491 ml in the group with autotransfusion as compared to 3202±1084 ml in the group with cardiotomy suction (NS). No oxygenator failure occurred during the perfusion procedures. However there was one cardiotomy reservoir inlet occlusion in a patient with a ruptured thoracoabdominal aortic aneurysm in whom several liters of clots were initially aspirated from his chest. This cardiotomy reservoir was replaced with a new heparin coated reservoir and the procedure was continued without further problem. After surgery, all the heparin coated perfusion sets were gently rinsed and carefully analyzed. There were no macroscopic deposits in the blood path of the venous reservoir or the heat exchanger/oxygenator structure and the outer shell of the cardiotomy reservoirs were clean. The key elements of a set with cardiotomy reservoir are shown in Figure 2. The heparin coated flexible venous reservoir, the heat exchanger, the arterial filter and the cardiotomy reservoir are free of macroscopic deposits. The cardiotomy reservoir can be better seen in Figure 3 where it becomes clear that the transparent outer shell is clean. The outflow of the filter section is depicted in Figure 4. There are no macroscopic clots visible. Chest tube drainage on day 1 was 878±421 ml for autotrans as compared to 690±520 ml for cardiotomy (NS). Thirty day survival was 10/10 (100%) for autotrans as well as 10/10 (100%) for cardiotomy (NS). In the group autotrans one patient died after 6 weeks (1/10: 10%) whereas all patients in the group cardiotomy survived.

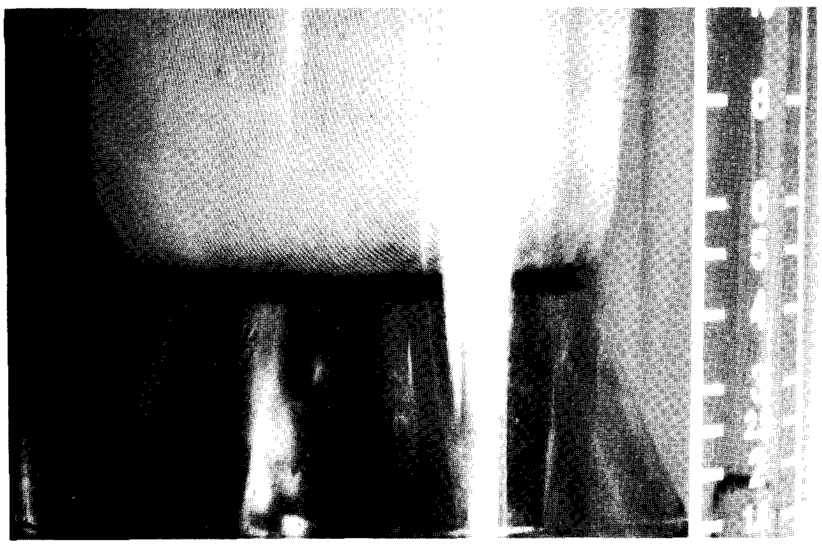

Figure 4
Macrophotograph of the outer aspect of the heparin coated cardiotomy filter section: no macroscopic deposits are visible

Similar problems can also occur in the filter section of a red cell spinning device. However, complex repair of descending thoracic and thoracoabdominal aortic aneurysms is greatly simplified with the practically unlimited capacity of shed blood recovery of cardiotomy suction. Hence, in our study there were slightly more intercostal and/or visceral patch reimplantations for the group with cardiotomy which translates also in longer aortic cross clamp times (43±17 versus 33±14 min: $p < 0.01$) and longer perfusion times (60±19 versus 41±17 min: $p < 0.05$) for this group. There was no difference for total heparin dose and the lowest ACT measured between the two groups. The target value of 180 s was measured several times in the two analyzed series and additional heparin was given if needed. Total protamine equivalent was somewhat lower for autotransfusion (7.8±2.1 10^3 IU versus 9.7±1.9 10^3 IU; $p < 0.05$). This is probably due to the fact that a significant amount of circulating heparin was removed in this group by the red cell spinning device that prepared in the group autotrans a mean amount of 3186±1318 ml washed and concentrated red cells versus 0 ml in the group cardiotomy ($p < 0.05$). Assuming a hematocrit of 60 % for the concentrate and 30% for the circulating blood, the washed blood volume can be estimated to about 6.3 L which is more than the estimated patient blood volume. A significant amount of heparin removed in these patients is therefore well explained.

Considering the complexity of the surgical procedures analyzed, the amount of homologous blood and blood products required, which is slightly less for the cardiotomy group, as well as the chest tube drainage, which is again less for the cardiotomy group, are very encouraging. In accordance to the protocol, red cell spinning was not used for the group perfused with cardiotomy suction.

We conclude that cardiotomy suction using heparin coated reservoirs for shed blood recovery during partial cardiopulmonary bypass with low systemic heparinization simplified repair of more complex descending thoracic aortic aneurysms and resulted in improved outcome. A significant reduction of transfusion requirements can be expected by the combined use of cardiotomy suction during perfusion and red cell spinning before heparinization and after heparin reversal with protamine.

DISCUSSION

Increased blood handling capacity is the most striking advantage of cardiotomy suction during repair of descending thoracic and thoracoabdominal aortic aneurysms with partial cardiopulmonary bypass and low systemic heparinization. The standard red cell spinning devices need about 3 minutes to prepare 270 ml of washed red cell concentrate with a hematocrit of up to 60% which is equivalent to about 166 ml of mean shed blood recovery per minute. In contrast the heparin coated cardiotomy reservoir can handle more than 10 times this amount over prolonged periods of time. The fact that the whole cardiac output can be maintained temporarily through a cardiotomy reservoir is well established. In our experimental evaluation (bovine experiments) the heparin coated cardiotomy reservoirs were challenged ex-vivo with an unheparinized blood flow of 3.6 L/min over 6 hours and no cardiotomy occlusion occured (10). The large blood handling capacity of the cardiotomy reservoir is of particular help during repair of large aneurysms as shown in Figure 1 where suddenly several liters of blood have to be aspirated. There can be even more benefit during surgery of ruptured aneurysms until control of the proximal aorta is achieved. However, the free blood in the thoracic cavity is, in general coagulated, at least in part, and therefore, it can often not be aspirated readily. This explains also the inlet obstruction of one cardiotomy reservoir that to be exchanged in the series presented.

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