Will the use of ultrafiltration during bypass reduce blood transfusion compared to conventional bypass.

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Abstract

Blood salvage is an important part of blood conservation effort in cardiac surgery. Blood transfusion is associated with increased morbidity and mortality after bypass. The purpose of this study is to reduce blood transfusion by applying ultrafiltration during bypass.

Twenty patients who underwent cardiac surgery were included in this study. Group A consisted of 10 patients where ultrafiltration was used during cardiopulmonary bypass (CPB) compared to group B which underwent conventional CPB.

The result for group A which underwent ultrafiltration, filtrated an amount of 695 ± 160.6 ml per patient. The average bank blood transfused was 1.42 ± 4.15 units per patient in group A and 0.1 ± 0.32 units per patient in group B, but did not give significant difference. It was concluded that ultrafiltration during CPB did not reduce blood transfusion.
Introduction

Blood transfusion is often a necessity in major surgery such as cardiac surgery. The rates of red blood cell (RBC) transfusion are high among patients undergoing cardiac surgical procedures. This study includes those patients undergoing coronary artery bypass graft (CABG) surgery, valve surgery or combined CABG/valve surgery. Patients who receive red blood cell (RBC) transfusions are associated with morbidity and short-term and long-term morbidity after cardiac surgery. In the literature one can find several articles and researches implying that 1- and 2-units of blood transfusions are standard, and that even these small amounts are associated with worse outcomes after cardiac operations (1, 2, 3, 4).

An important part of blood conservation efforts in cardiac surgery is intraoperative blood salvage. In open heart surgery the role of blood conservation techniques has expanded through contributions in reducing the quantity of homologous blood products. The awareness of the risks associated with transfusion has increased considerably. Especially after the discovery of the transmission of human immunodeficiency virus by administration of homologous blood transfusion. Transmission of infections are not the only the potential risks associated with blood transfusion. Hemolytic, febrile or allergic reaction, acute lung injury or alloimmunization may appear after blood transfusion (5).

Ultrafiltration (UF) is currently considered as a standard method to remove excess water administered during cardiac surgery. Although ultrafiltration is more used in pediatric surgery due to volume management on these patients, it is also used in adult surgery. Ultrafiltration also aims to minimize the adverse effects of hemodilution, such as tissue edema and blood transfusion. Originally ultrafiltration (UF) was adapted from a renal dialysis technique. It is used to provide an artificial replacement for kidney dysfunction in patients with renal failure by removing waste and excess water from blood.

By removing plasma water directly across a semipermeable membrane using hydrostatic forces
ultrafiltration can reverse hemodilution during CPB (6).

The effort to minimizing the use of blood products in cardiac surgery is growing. The literature concerning blood transfusion complications suggest that transfusion should be avoided to the extent possible and to apply a restrictive transfusion strategy (2, 3, 4). Blood conservation methods are a manageable solution in reducing blood products. The use of ultrafiltration during cardiac surgery helps to concentrate the blood and is commonly used as a blood management method.

The aim of this study is to compare two groups of patients, where group A is the group using ultrafiltration during CPB, and group B conventional CPB. The primary value of comparison is the hemoglobin (Hb) level of the patients.
Methods and Material

This study consisted of 20 patients, randomly allocated to one of two groups. In group A, 10 patients underwent cardiac surgery with CPB and conventional ultrafiltration (CUF). In group B, 10 patients underwent cardiac surgery with conventional CPB. 20 unmarked envelopes were made, each containing a note indicating if ultrafiltration was to be applied or not. The main criteria for the study patients was to have a hemoglobin value of 9.5-13.5 g/dL of the first blood gas taken after the patient had entered the operating room. Patients undergoing combined cardiac surgery (example AVR + CABG) were excluded. If the Hb met the criteria, an envelope was selected to decide which group the patient will partake. Patient from group A which received ultrafiltration, were then compared with group B, which did not receive ultrafiltration during CPB.

Equipment used was a Stöckert (S5, Sorin Group, München Germany) heart lung machine (HLM). Tubing, hard-shell reservoir (VHK-71000) and oxygenator (Quadrox-i) from Maquet (Getinge Group, Rastatt Germany). Ringer acetat was used for the priming solution. Cobas b 211 (Roche Diagnostics, Indianapolis USA) and ABL 800 (Radiometer Medical, Brønshøj Denmark) was the machines used for the blood gas samples. Sorin’s adult hemoconcentrator DHF 0.6 was used for the ultrafiltration.

The ultrafiltration process was initiated after cardioplegia was given and placed between the arterial filter purge line and the venous reservoir. Filtering until the excess volume in the CPB circuit was in a reduced level, safe for termination of CPB.

Procedures for coronary artery bypass grafting CABG, aortic valve replacement (AVR) and mitral valve plasty (MPL) where different in priming volume and cardioplegia technique. For CABG patients, the priming solution was 1800ml of Ringer acetat, and crystalloid cardioplegia with normothermia (37°C). For AVR patients, the priming solution was 2000ml of Ringer acetat, and blood cardioplegia with a ratio of 1:4 with moderate hypothermia (34°C). For MPL patietns, the priming was 1800ml of Ringer acetat, and custodiol cardioplegia with moderate hypothermia (34°C).
For all patients, blood gas was taken right after arrival in the operating room (anesthesia took the blood gas), at start of CPB (blood taken from HLM), in the middle of CPB (blood taken from HLM), after CPB end (anesthesia took the blood gas) and post-operative blood gas the day after. All the blood gas samples used the Cobas b 221 machine except for the post-operative blood gas, were ABL 800 was used. After cessation of cardioplemonary bypass the remaining blood in the circuit was transferred into a transfusion bag and given back to the patient.

All the data are shown as mean ± standard deviation and was statistically analyzed using Student’s t-test analysis. A p-value less than 0.05 (p<0.05) were defined as statistical significant.
Results

Results are expressed as mean values ± standard deviations. The level of significance was calculated by a two-tailed Student's T-test analysis.

The two groups were comparable with respect to demographic and operative data. There were no significant differences in the patients age, gender and weight or CPB or aortic cross-clamp time (Table 1).

Table 1. Patient data

<table>
<thead>
<tr>
<th>Category</th>
<th>Group A</th>
<th>Group B</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>65 ± 11.2</td>
<td>66 ± 9.3</td>
<td>0.915</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>80 ± 16.3</td>
<td>82 ± 14.1</td>
<td>0.773</td>
</tr>
<tr>
<td>BSA (m²)</td>
<td>1.96 ± 0.18</td>
<td>1.99 ± 0.18</td>
<td>0.779</td>
</tr>
<tr>
<td>CPB (min)</td>
<td>92 ± 37</td>
<td>79 ± 31</td>
<td>0.381</td>
</tr>
<tr>
<td>X-CLAMP (min)</td>
<td>57 ± 32</td>
<td>51 ± 24</td>
<td>0.649</td>
</tr>
<tr>
<td>REPERF (min)</td>
<td>26 ± 8</td>
<td>22 ± 9</td>
<td>0.309</td>
</tr>
<tr>
<td>Gender</td>
<td>9 / 1</td>
<td>9 / 1</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: BSA = body surface area; CPB = cardiopulmonary bypass time; X-CLAMP = aortic cross clamp time; REPERF = reperfusion time

In Table 2, the hemoglobin values for both groups are shown. In group A the preoperative hemoglobin averaged 12.0 ± 1.1 g/dL and was comparable to group B which was 11.8 ± 1.3 g/dL. In the start of cardiopulmonary bypass the Hb was 8.5 ± 1.0 g/dL in group A and 8.2 ± 0.9 g/dL in group B. In the middle of CPB the Hb was 9.5 ± 1.0 g/dL whereas in group B, 9.4 ± 1.0 g/dL. After CPB was terminated the Hb was 9.7 ± 1.4 g/dL in group A and was similar to group B which was 9.4 ± 1.3 g/dL. In group A the post-operative Hb averaged 11.4 ± 0.9 g/dL which was slightly higher than group B which averaged 10.8 ± 0.7 g/dL.
Table 2. Hemoglobin values

<table>
<thead>
<tr>
<th>Category</th>
<th>Group A</th>
<th>Group B</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preop Hb (g/dL)</td>
<td>12 ± 1.1</td>
<td>11.8 ± 1.3</td>
<td>0.661</td>
</tr>
<tr>
<td>Start CPB Hb (g/dL)</td>
<td>8.5 ± 1.0</td>
<td>8.2 ± 0.9</td>
<td>0.474</td>
</tr>
<tr>
<td>Mid CPB Hb (g/dL)</td>
<td>9.5 ± 1.0</td>
<td>9.1 ± 1.0</td>
<td>0.344</td>
</tr>
<tr>
<td>End CPB Hb (g/dL)</td>
<td>9.7 ± 1.4</td>
<td>9.4 ± 1.3</td>
<td>0.637</td>
</tr>
<tr>
<td>Postop Hb (g/dL)</td>
<td>11.4 ± 0.9</td>
<td>10.8 ± 0.7</td>
<td>0.122</td>
</tr>
</tbody>
</table>

Abbreviations: Preop = preoperative; Hb = hemoglobin; CPB = cardiopulmonary bypass; Postop = postoperative

In Table 3, fluid data is shown. The mean cardioplegia given in group A was 1090ml and in group B 1113ml. With regard to blood transfusiot intraoperative, the mean amount of blood transfused was 0.2 ± 0.42 units in group A and 0.2 ± 0.63 units in group B. The mean amount ultrafiltrated in group A was 695 ± 161 ml per patient. Crystalloids added during CPB in group A average of 470 ± 353 ml compared to group B with 140 ± 227 ml which was significantly lower (p < 0.05). Post operative transfusion in group A was higher in group A with 1.42 ± 4.15 units per patient compared to 0.1 ± 0.32 units per patient, but there was no significance difference (one patient had bleeding complication postoperative). Lastly, the number of patients transfused was 3/10 in group A, and 2/10 in group B.

Table 3. Fluid data

<table>
<thead>
<tr>
<th>Category</th>
<th>Group A</th>
<th>Group B</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardioplegia</td>
<td>1090 ± 424.8</td>
<td>1112.5 ± 253.6</td>
<td>0.899</td>
</tr>
<tr>
<td>Transfusion (intraop)</td>
<td>0.2 ± 0.42</td>
<td>0.2 ± 0.63</td>
<td>1</td>
</tr>
<tr>
<td>Filtered</td>
<td>695 ± 160.6</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Crystalloid added (intraop)</td>
<td>470 ± 352.9</td>
<td>140 ± 227.1</td>
<td>0.025*</td>
</tr>
<tr>
<td>Postop transfusion</td>
<td>1.42 ± 4.15</td>
<td>0.1 ± 0.32</td>
<td>0.342</td>
</tr>
<tr>
<td>No of pts trans</td>
<td>3</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

*Statistically significant

Abbreviations: intraop = intraoperative; postop = postoperative
Discussion

In this study, a common ultrafiltration method CUF, was applied during cardiopulmonary bypass to see if it reduces blood transfusion in cardiac surgery. Several studies have showed that the CUF method is not successful in reducing blood transfusion or other blood products. It is better used in volume management during CPB (6, 8, 11). This has corresponded with the findings of this study where most of the blood related samples have been similar except for the blood transfusion rates in the study group which was relatively higher than the control group, but was not significant.

The main function of ultrafiltration is the removal of water and small molecules such as electrolytes, and where large molecules such as blood cells and protein, remain preserved and concentrated. Previous studies have reported benefits of ultrafiltration. Benefits such as decreasing extravascular lung water, reduction in circulatory inflammatory mediators, improved neurologic outcome, and raising the heamatocrit/hemoglobin and improving haemostasis, postoperatively (6, 7, 9, 10). Findings in this study showed an increase in hemoglobin value postoperatively in the ultrafiltration group compared to the control group, but was not significant.

Conventional ultrafiltration (CUF) is successful in removing fluid, and much of this is usually returned as crystalloid to maintain circulating volume during CPB (9, 10). This has corresponded with the findings in this study, where the nonblood liquid (crystalloids) added during CPB was significantly (p<0.025) higher in the ultrafiltration group compared to the control group.

The study of Eichert et al compared three different circuit blood salvage techniques. In the following comparison, direct infusion method where the remaining post cardiopulmonary bypass blood in the circuit is given back to the patient and the use of ultrafiltration of post CPB blood before giving it back to the patient, showed that the postoperative hemoglobin was higher in the direct infusion method (5). However, in this study, conventional ultrafiltration and direct infusion was used on the study group, and showed a slightly higher postoperative hemoglobin value than the control group which only had the direct infusion method.
In this study, we could not demonstrate any significant elevation of hemoglobin in any of the stages during CPB or postoperative. Like mentioned earlier this can be due to a restoration of the volume removed by the ultrafiltration with nonblood volume causing a hemodilutional effect. Other studies suggest that a different method of ultrafiltration has a better outcome when it comes to increasing the hemoglobin/hematocrit postoperatively. Modified ultrafiltration (MUF) is an alternative method which is commonly used in pediatric surgery and infrequently used in adult surgery (7). The study of Sever et al looked at the benefits of continuous ultrafiltration in pediatric cardiac surgery. The results revealed that MUF significantly increases hemoglobin and hematocrit levels compared to conventional ultrafiltration in this population (8).

This study failed to demonstrate the reduction of blood transfusion. Intraoperative transfusion was similar in both groups. Even though the transfusion rate was higher in the study group postoperatively, it was not significant. The higher transfusion rate in group A was due to a patient bleeding postoperative increasing the mean transfusion rate per patient.

There are limitations and improvements that can be done with this study. Firstly, the HLM priming and cardioplegia technique should have been the same for all patients. The different cardioplegia techniques can give a more hemodilution in one method than another. For instance, the use of custodial cardioplegia with a total amount of approximately 1800 ml, compared to approximately 600 ml in blood cardioplegia method.

The effectiveness of the ultrafiltration is limited by the minimum level in the venous CPB reservoir. Lastly, there could have been more data to be considered in the study intraoperative and postoperative, such as preoperative heart conditions and patient status postoperatively.
Conclusion

In this study, ultrafiltration has shown to increase the hemoglobin values during CPB in cardiac surgery during intraoperative and postoperative, but does not reduce the blood transfusion for these patients. A greater increase of hemoglobin values must be achieved, and the findings in this study have failed to demonstrate that. Although the study could not show any reduction in blood transfusion, ultrafiltration has the potential to avoid homologous transfusions in consideration of the complications it can cause to the patients undergoing cardiac surgery.
References


Supporting literature

Gravlee GP, Davis RF, Stammers AH, Ungerleider RM. Cardiopulmonary bypass, principles and practice, third edition. Lippincott Williams & Wilkins. 2008; 6: 114-128