Original Article

Bilateral Extracorporeal Circulation ("Drew Technique") for Coronary Artery Bypass Surgery using Patient’s Lung as Oxygenator

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ABSTRACT

The aim of this study was to determine: 1) whether a bilateral perfusion circuit (Drew technique) using the patient’s own lung as the oxygenator is feasible for multi-vessel coronary artery bypass grafting; and 2) if the systemic inflammatory response to extracorporeal circulation differs compared to conventional cardiopulmonary bypass procedures.

Twenty patients were enrolled in a randomized, controlled study. In the Drew group (n=10) bilateral perfusion was used. The other patients (n=10) were operated on with conventional perfusion techniques and served as the control group. Pro- (interleukin-6) and anti-inflammatory (interleukin-10) mediators were measured before operation, during rewarming, 30 min, 2, 4, and 24 hours after extracorporeal circulation.

The results show that: 1) multi-vessel coronary artery bypass grafting could be performed during 90 ± 8 min of bilateral cardiopulmonary bypass; 2) the concentration of the interleukin-6 was significantly lower in the Drew group at 2 hours (449 ± 82 versus 914 ± 152 pg/ml, p = 0.02), and 24 hours (146 ± 38 versus 424 ± 98 pg/ml, p = 0.02), after cardiopulmonary bypass.

The Drew technique seems to be a promising method of extracorporeal circulation which: 1) can safely be used during routine coronary bypass grafting procedures; and 2) significantly reduces the systemic inflammatory response as compared to conventional extracorporeal circulation.

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INTRODUCTION

Bilateral bypass without an oxygenator was introduced in the late 1950s by British cardiac surgeon Charles Drew (1-4). The “Drew Technique” is a form of extracorporeal circulation without using an artificial oxygenator. The patient’s own lungs are used instead. The oxygenators that were available when Charles Drew introduced bilateral cardiac bypass were associated with various uncertainties for the patients. Therefore, using the patient’s own lungs for oxygenation was a safe and reliable approach. The operations performed were mainly corrections of congenital heart disease. Extracorporeal circulation was used for cooling and rewarming, while the cardiac surgery was done during deep hypothermic circulatory arrest (3). The method was later used in coronary artery bypass patients (5, 6).

The use of cardiopulmonary bypass induces a well described systemic inflammatory response syndrome (7). A significant number of patients develop organ dysfunction, which delays the postoperative course and is a major reason for morbidity and mortality (8-11). The immune response during cardiac surgery has been the subject of several investigations and a well described pro-inflammatory response exists with increased plasma concentrations of tumor necrosis factor (12), interleukin-1 (13), interleukin-6, and interleukin-8 (14-16). An anti-inflammatory reaction manifested by elevation of interleukin-10 (17, 18) has been demonstrated to follow the expression of the pro-inflammatory cytokines. In view of the effort made to diminish the inflammatory response syndrome by using filtration techniques (19, 20) or anti-inflammatory pharmacological interventions (21) bilateral bypass seems to be attractive, since the artificial oxygenator is excluded from the circuit. With the bilateral extracorporeal system, the surface of foreign material exposed to the blood can be considerably reduced (5).

The aim of this study was to determine: 1) whether using the patient’s own lung as an oxygenator in a bilateral perfusion circuit was feasible for routine coronary artery bypass grafting in patients with multi-vessel coronary artery disease; and 2) if the systemic inflammatory response to extracorporeal circulation differed compared to conventional cardiopulmonary bypass procedures with a membrane oxygenator.

MATERIALS AND METHODS

The present investigation was performed in accordance with the principles of the declaration of Helsinki 1964 and its later revisions. The study protocol was approved by the Institutional Ethical Committee. Written, informed consent from each patient was obtained.

Twenty patients, scheduled for coronary artery bypass grafting, NYHA groups II and III, ASA physical status groups III and IV, were investigated. They were randomly assigned to one of the two groups: the Drew group (n=10), extracorporeal circulation without oxygenator (Figure 1), or the control group (n=10) conventional cardiopulmonary bypass circuit including a membrane oxygenator.

CARDIOPULMONARY BYPASS TECHNIQUE

The cardiopulmonary bypass equipment consisted of roller pumps*. The priming was identical in the two groups (Table 1). Cardiopulmonary bypass was instituted at a flow rate of 2.4 L/min/m² BSA after systemic heparinization. The body temperature was reduced to 28°C by cooling on bypass. After cross-clamping the aorta, 1000 ml cold crystalloid cardioplegic solution† was administered. The blood remaining in the bypass circuit was washed and centrifuged using a cell-separator system‡

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† Bretschneider, Custodiol, Köhler Chemie, Alsbach-Hähnlein, Germany
‡ Cell-Saver V, Haemonetics, München, Germany
before retransfusion. The differences between the material used for the conventional and the Drew circuit are shown in Table 2.

An aortic cannula (A232-80) was used in all patients. For cannulation of the right atrium a wire reinforced venous catheter (Two Stage, F40-32, V900-19) was applied. There are two additional cannulas necessary for the Drew group. For the pulmonary artery: a wire reinforced venous catheter (V122-24, 24 French), and for the left atrium: a wire reinforced venous catheter (V122-28, 28 French).

LABORATORY INVESTIGATIONS

Blood samples were obtained and hemodynamic measurements were performed at the following time points: 1) before induction of anesthesia; 2) during extracorporeal circulation before rewarming; 3) 30 min after extracorporeal circulation; 4) 2 h after extracorporeal circulation; 5) 4 h after extracorporeal circulation; and 6) 24 h after extracorporeal circulation.

The blood was collected in different phlebotomy tubes: EDTA containing tubes for interleukin-10, serum tubes containing no anticoagulant for the measurement of interleukin-6, which was measured using a solid-phase, two-site chemiluminescent enzyme immunometric assay. Interleukin-10 was measured with a solid-phase ELISA in microtiter plates.

ANESTHESIA TECHNIQUE

For anesthesia a totally intravenous technique was used. Induction of anesthesia was performed with 1 μg/kg sufentanil, 0.04 mg/kg midazolam, and 0.1 mg/kg pancuronium. A “loading dose” of 6 μg/kg sufentanil and 0.3 mg/kg midazolam was given before sternotomy. Thereafter the infusion was adjusted to 0.5 μg/kg/h sufentanil and 0.02 mg/kg/h midazolam and maintained until the end of the operation. Dopamine (3 μg/kg/min) was used throughout the procedure for maintenance of adequate urine output. Before separation from cardiopulmonary bypass dopamine was increased to 5 μg/kg/min. After termination of cardiopulmonary bypass, the infusion rate was set according to the patient’s circulatory state. A cardiac index ≥ 2.3 L/min/m², and a mean arterial pressure ≥ 60 mmHg were the targets. Aprotinin was given according to the Hammersmith protocol in all patients.

STATISTICS

Nonparametric statistical methods were used to analyze the skewed biochemical data: comparisons within groups were assessed with the Wilcoxon signed-rank test and comparisons between groups with the Mann-Whitney U test. A p-value of < 0.05 on a two-tailed test was considered statistically significant. The data are presented as mean ± sem. The statistical software SPSS for Windows version 7.0 was used.

RESULTS

OPERATION AND DEMOGRAPHIC DATA (MEAN ± SEM)

There were no significant differences with regard to intraoperative and demographic data when comparing the 2 groups (Table 3).

BILATERAL PERFUSION TECHNIQUE

The results revealed that routine coronary artery surgery is possible using bilateral perfusion. Oxygenation can safely be assured using the patient’s own lung. No technical problems or difficulties with oxygenation occurred throughout the study period. The cannulation procedure has been shown to be done best in the following sequence: aorta, pulmonary artery, right atrium. Thereafter right heart bypass was started. After cannulation of the left atrium, the left heart bypass was started. The flow of the right heart bypass was kept 0.2-0.3 L/min higher than for the left-sided circulation. The shunt between the left and the right reservoir can be used to balance the levels between the two reservoirs (Figure 1). It was seen that differences in the blood levels between the two reservoirs can also be balanced by changing the respective pump speed.

The alveolar ventilation of the patients during bilateral bypass could be reduced as temperature decreases. Continuous measurement of blood gases and acid base balance made it easy to control ventilation and oxygenation. The inspired oxygen fraction was set between 0.4 and 0.6 in all patients, which resulted in an arterial oxygen tension of more than 100 mmHg.

After aortic cross-clamping the cardioplegic solution was given in the aortic root and the patients were cooled down to 28°C core temperature. Pulsatile flow was set at 70 beats, 70% pulse duration, 40% base flow. Continuous flow was used before release of the aortic clamp. The circuits were weaned off sequentially and the remaining blood volume transferred to the still running circuit. During this investigation the right heart bypass was weaned first in all patients. The remaining blood in the extracorporeal circuit was salvaged using a system for auto-

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Table 1: Priming

<table>
<thead>
<tr>
<th>Component</th>
<th>Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ringer’s Lactate</td>
<td>1500 ml</td>
</tr>
<tr>
<td>NaHCO₃ 4.2% (5 ml/kg)</td>
<td>max 200 ml</td>
</tr>
<tr>
<td>Mannitol 20% (3 ml/kg)</td>
<td></td>
</tr>
<tr>
<td>Inzulen®</td>
<td>20 ml = 20 mval KCl</td>
</tr>
<tr>
<td>Heparin (1 ml = 5000U)</td>
<td>1 ml</td>
</tr>
</tbody>
</table>

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reservoir was disassembled and connected to the chest-tubes. Postoperative shed blood was retransfused within the first six hours.

Table 2: Equipment for extracorporeal circulation

<table>
<thead>
<tr>
<th>Standard</th>
<th>Drew Technique</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2&quot; venous tubing (from right atrium)</td>
<td>1/2&quot; venous tubing (from right atrium)</td>
</tr>
<tr>
<td>Combined venous and cardiotomy reservoir (D772, Venocard)</td>
<td>Combined venous and cardiotomy reservoir (D772, Venocard)</td>
</tr>
<tr>
<td>3/8&quot; silicone racetrack tubing</td>
<td>3/8&quot; silicone raceway tubing</td>
</tr>
<tr>
<td>Roller-pump head</td>
<td>Roller-pump head</td>
</tr>
<tr>
<td>Membrane oxygenator with integrated heat exchanger (Compactflo, Module 7500)</td>
<td>External heat exchanger (D720A, Helios)</td>
</tr>
<tr>
<td>3/8&quot; pvc arterial line tubing (to aorta)</td>
<td>3/8&quot; pvc arterial tubing (to aorta)</td>
</tr>
<tr>
<td>Pressure monitoring</td>
<td>Pressure monitoring</td>
</tr>
<tr>
<td>Arterial filter (D734, Micro 40)</td>
<td>Arterial filter (D734, Micro 40)</td>
</tr>
<tr>
<td>2 sucker-lines and roller-pumps</td>
<td>2 sucker-lines and roller-pumps</td>
</tr>
<tr>
<td>Pre-bypass filter (during flushing and de-airing the system) (R3802 Pre Bypass Plus with vent)</td>
<td>Pre-bypass filter (during flushing and de-airing the system) (R3802 Pre Bypass Plus with vent)</td>
</tr>
</tbody>
</table>

Table 3: Operative and demographic data (mean ± sem)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Drew</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age [years]</td>
<td>68 ± 2</td>
<td>64 ± 2.5</td>
</tr>
<tr>
<td>Height [cm]</td>
<td>174 ± 2</td>
<td>169 ± 2</td>
</tr>
<tr>
<td>Weight [kg]</td>
<td>82 ± 3</td>
<td>76 ± 2</td>
</tr>
<tr>
<td>CPB [min]</td>
<td>90 ± 8</td>
<td>103 ± 11</td>
</tr>
<tr>
<td>Cx [min]</td>
<td>59 ± 6</td>
<td>66 ± 8</td>
</tr>
<tr>
<td>No. of anastomoses distal</td>
<td>3.4 ± 0.4</td>
<td>3.3 ± 0.3</td>
</tr>
<tr>
<td>No. of anastomoses aortic</td>
<td>1.7 ± 0.3</td>
<td>1.7 ± 0.2</td>
</tr>
</tbody>
</table>

CPB: duration of cardiopulmonary bypass; Cx: duration of aortic cross clamping

Table 4: Interleukin-6 concentrations [pg/ml] (mean ± sem)

<table>
<thead>
<tr>
<th>Time</th>
<th>Drew</th>
<th>Control</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>baseline</td>
<td>6.3 ± 3.9</td>
<td>23.5 ± 5.7</td>
<td>0.1</td>
</tr>
<tr>
<td>CPB begin rewarming</td>
<td>38.1 ± 17.6</td>
<td>30.1 ± 8.3</td>
<td>0.6</td>
</tr>
<tr>
<td>CPB + 30 min</td>
<td>182.0 ± 19.0</td>
<td>330.9 ± 87.2</td>
<td>0.1</td>
</tr>
<tr>
<td>CPB + 2 h</td>
<td>449.0 ± 81.5</td>
<td>913.6 ± 151.8</td>
<td>0.02</td>
</tr>
<tr>
<td>CPB + 4 h</td>
<td>766.5 ± 223.9</td>
<td>1329.5 ± 199.7</td>
<td>0.08</td>
</tr>
<tr>
<td>CPB + 24 h</td>
<td>146.2 ± 37.7</td>
<td>423.6 ± 97.6</td>
<td>0.02</td>
</tr>
</tbody>
</table>

Interleukin-6 increased slightly after induction of anesthesia and further after initiation of CPB in both groups (Table 4). The peak level of interleukin-6 was at 4 h after cardiopulmonary bypass. In the Drew group, the concentration of interleukin-6 was significantly lower at 2 h and 24 h after cardiopulmonary bypass.

The peak level of interleukin-10 was found 30 min after the end of cardiopulmonary bypass (Table 5). The concentration was 301.3 ± 169.7 pg/ml in the Drew group versus 129 ± 27.7 pg/ml in the control group. The difference, however, did not reach the level of significance.

**DISCUSSION**

**LIMITATIONS**

The main limitations of the bilateral oxygenation technique are its restricted use for patients undergoing coronary artery operations and the lack of the safety of an oxygenator for emergency situations. The bilateral bypass is more complex than the standard extracorporeal circulation because of the two separate circuits. Additional cannulation of the pulmonary artery and the left atrium is needed.

One limitation of the study is the limited number of patients (n=20). The demonstrated decrease in activation of the inflammatory response therefore has to be interpreted with caution. Further investigations using the Drew technique are needed to confirm these results and to further elucidate the pulmonary function during and after bilateral cardiopulmonary bypass.

**BILATERAL PERFUSION TECHNIQUE**

Theoretically, it is possible to start the perfusion with either of the two circuits. However, it has been confirmed that cannulation of the left atrium is much easier when right-heart bypass was already started and the right heart was empty. At the end of extracorporeal circulation, the same sequence has been shown to be recommendable. The left-heart bypass was stopped first, then if circulation was stable, the left atrial cannula was removed. Then, the right-heart bypass was weaned. Figure 1 shows a line between the venous and the arterial reservoir. This shunt can be used in the case of obstruction of one reservoir and then retransfused to the patient. One of the reservoirs was disassembled and connected to the chest-tubes. Postoperative shed blood was retransfused within the first six hours.
INFLAMMATORY RESPONSE

There are two major differences found between the Drew group and the control patients. First, the pro-inflammatory interleukin-6 is significantly lower in the Drew group 2 and 24 h after cardiopulmonary bypass. Second, the anti-inflammatory interleukin-10 showed a tendency to be higher in the Drew group.

Recent findings underline the fact that steroids may also inhibit the inflammatory response to extracorporeal circulation (21-23), and that they greatly enhance the production of the anti-inflammatory interleukin-10 (18, 24). These effects are very similar to the results found using bilateral circulation. However, since the inflammatory response is multifactorial, combined therapies may be more efficient than a single intervention to improve outcome. Both pharmacological interventions and modifications of extracorporeal techniques might improve clinical benefits.

In conclusion, the Drew technique seems to be a promising method for reducing the systemic inflammatory response as compared to conventional extracorporeal circulation. This technique may also provide a technique for use in underdeveloped countries with restricted resources for disposable oxygenators.

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