Case Report

**Bloodless Prime in Pediatric Cardiopulmonary Bypass Circuits**

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**Abstract**

Hemodilution during cardiopulmonary bypass is a well-established practice. In pediatric cardiac surgery the volume of the prime may cause excessive hemodilution. In most institutions hemodilution in pediatric patients is controlled by adding blood to the prime. This case involves a female patient weighing 15.4 kilograms who received no blood other than that recovered during her surgery.

The blood was processed in a cell washing device. A 968 milliliter clear prime was utilized. The data collected during and post bypass was examined and demonstrated the adequacy of perfusion in this patient. Parameters utilized to demonstrate the adequacy of perfusion include pH, urine output and venous oxygen saturation.

**Introduction**

Blood utilization in the prime of pediatric cardiopulmonary bypass circuits is a commonly accepted practice. The rationale for this is that hemodilution occurring in bloodless circuits would decrease the oxygen carrying capacity, the osmolarity and the viscosity of the perfusate beyond the tolerable limits of pediatric patients. At this institution different criteria are now being used to distinguish between pediatric patients who are able to withstand hemodilution and those who require a blood prime. The criteria used to identify patients for whom a non-blood prime is appropriate are: first, the estimated hematocrit on bypass must be 17 percent or greater; second, the patient’s blood chemistry and coagulation status must be within normal limits, except for conditions which can be directly attributed to the defect; third, autotransfusion must be utilized throughout the procedure so that the maximum possible post bypass hematocrit may be achieved.

This case involves a 15.4 kilogram female on whom atrial septal defect, secundum type, repair was performed. Extreme care was taken to salvage all blood during bypass and the remaining pump volume after termination of bypass. This patient received only autologous blood during her stay in the hospital. Very little has been written about this technique; therefore, it warrants reporting.

**Materials and Methods**

The cardiopulmonary bypass circuit consisted of a Cobe VPCML membrane oxygenator, an Olson custom pediatric pack, Pall prebypass filter, Pall AV3 arterial line filter and a GEM-6 Plus in-line blood gas analyzer. Autotransfusion was employed throughout the procedure using the Haemonetics Cell Saver 3 Plus with a 125 ml bowl. The prime consisted of 900 ml of lactated Ringer’s solution (LR), 2.8 mg/kg mannitol, 25 mEq sodium bicarbonate and 2000 USP units of beef lung heparin.

Crystalloid cardioplegia was delivered by means of a roller pump. A dose of 15 ml of crystalloid cardioplegia per kg patient weight was calculated. The pre-bypass activated clotting time (ACT) was determined to be 140 seconds using the handheld method. A loading dose of 3000 units/kg of heparin was administered and an ACT performed five minutes later was 350 seconds. An additional 3000 units of heparin was given to the patient pre-bypass which resulted in a pre-bypass ACT of 675 seconds.

The patient was placed on bypass and cooled. After five
minutes the nasopharyngeal temperature was 29.4°C, the
cardiac index (CI) was 1.6 l/m²/min and the mean arterial
pressure (MAP) was 25 mmHg. The gas sweep rate and FiO₂
remained at 2.5 LPM and 70 percent, respectively. An ACT
was performed with a result of 735 seconds. The aorta was
clamped at this time and 230 ml of cardioplegia was delivered
into the aortic root. Arterial and venous blood samples were
taken after five minutes on bypass and analyzed on the GEM
6 Plus. The results, using the alpha stat method, are shown in
Table 1. A centrifuged Hct was performed at this time for
comparison. The result was 17 percent.

In order to elevate the MAP, the blood flow was increased
to 2.2 l/m²/min resulting in a MAP of 35 mmHg.

Following the blood gas result, the gas sweep rate was
decreased to 1.75 LPM and the FiO₂ was decreased to 55
percent to bring the arterial blood gas to within normal limits.
75 ml of LR was added to the circuit via the venous reservoir
in order to maintain an adequate operating level.

After 20 minutes on bypass, the patient’s temperature was
29.2°C. A second set of blood gases was performed at this
time. The results are shown in Table 1. The centrifuged Hct at
this time was 18 percent.

After 25 minutes on bypass, warming of the patient was
initiated. At this time, the arterial blood flow rate was at 2.2 l/
m²/min, the MAP was 33 mmHg, the sweep rate and the FiO₂
were increased to 2.0 LPM and 65 percent respectively.

After 36 minutes on bypass the patient’s nasopharyngeal
temperature was 30°C. No changes were made in the arterial
blood flow, gas sweep rate or FiO₂. A third blood gas analysis
was performed. The results are in Table 1.

At this time the arterial blood flow rate was increased to 2.6
l/m²/min in order to raise the venous oxygen saturation. The
MAP remained at 35 mmHg. The gas sweep rate remained at
2.0 LPM and the FiO₂ was increased to 70 percent. 125 ml of
LR was added to the circuit via the venous reservoir in order
to maintain a safe operating level.

After 38 minutes on bypass, the patient’s nasopharyngeal
temperature was 38°C. The aortic clamp was removed and the
arterial blood flow was increased to 3.4 l/m²/min to meet the
patient’s higher oxygen requirements due to the temperature
change. The MAP, gas sweep rate and FiO₂ remained un-
changed.

At 46 minutes after initiation of bypass, the patient was
weaned from bypass with a MAP of 60 mmHg and pulmonary
artery diastolic pressure of 10 mmHg.

An ACT was performed just prior to termination of bypass
with a result of 515 seconds. The protamine dose of 100 mg
was given to the patient. The dose was determined using a Bull
Dose Response Curve1. The remaining perfusate from the
circuit was processed using the cell saver resulting in a total of
250 ml of autologous red blood cells, which was transfused
immediately following bypass. Table 2 compares the Hct,
platelet count, arterial oxygen saturation and arterial pH
preoperatively, immediately post-pump and 24 hours postop-

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### Table 1

<table>
<thead>
<tr>
<th>Time on bypass</th>
<th>pH</th>
<th>pCO₂</th>
<th>HCO₃</th>
<th>pO₂</th>
<th>SAT %</th>
<th>Hct</th>
<th>BE</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 min art.</td>
<td>7.50</td>
<td>34</td>
<td>26.4</td>
<td>544</td>
<td>100</td>
<td>19</td>
<td>+3.4</td>
</tr>
<tr>
<td>5 min ven.</td>
<td>7.40</td>
<td>42</td>
<td>25.0</td>
<td>293</td>
<td>99.9</td>
<td>19</td>
<td>+1.0</td>
</tr>
<tr>
<td>20 min art.</td>
<td>7.41</td>
<td>40</td>
<td>25.4</td>
<td>229</td>
<td>99.9</td>
<td>19</td>
<td>0</td>
</tr>
<tr>
<td>20 min ven.</td>
<td>7.36</td>
<td>46</td>
<td>29.0</td>
<td>237</td>
<td>99.8</td>
<td>19</td>
<td>0</td>
</tr>
<tr>
<td>36 min art.</td>
<td>7.42</td>
<td>38</td>
<td>24.4</td>
<td>237</td>
<td>99.8</td>
<td>19</td>
<td>0</td>
</tr>
<tr>
<td>36 min ven.</td>
<td>7.36</td>
<td>46</td>
<td>29.0</td>
<td>237</td>
<td>99.8</td>
<td>19</td>
<td>0</td>
</tr>
<tr>
<td>45 min art.</td>
<td>7.34</td>
<td>45</td>
<td>24.0</td>
<td>250</td>
<td>99.8</td>
<td>18</td>
<td>+0.5</td>
</tr>
<tr>
<td>45 min ven.</td>
<td>(no time for a venous sample)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 2

<table>
<thead>
<tr>
<th>Time</th>
<th>Hct</th>
<th>Platelet count</th>
<th>Arterial pH</th>
<th>Arterial Sat</th>
</tr>
</thead>
<tbody>
<tr>
<td>pre-bypass</td>
<td>33.5</td>
<td>423,000</td>
<td>7.43</td>
<td>99%</td>
</tr>
<tr>
<td>post-bypass</td>
<td>28.7</td>
<td>227,000</td>
<td>7.41</td>
<td>99%</td>
</tr>
<tr>
<td>24 hr postop</td>
<td>30.1</td>
<td>270,000</td>
<td>7.39</td>
<td>99%</td>
</tr>
</tbody>
</table>
Hemodilution during cardiopulmonary bypass is a well-established practice\textsuperscript{2-6}. Utilization of a clear prime in pediatric cardiopulmonary bypass circuits, as was first attempted during the 1970s, has not gained wide acceptance\textsuperscript{7}.

This case is an example of a patient who received the benefits of a bloodless prime without being hemodiluted beyond her limits of tolerance. The benefits are exemplified through careful examination of the case data.

The major benefit of using a bloodless prime with autologous transfusion is that the patient is not exposed to blood products which may cause transfusion reactions, precipitate formation of atypical antibodies or be a source of viral infection\textsuperscript{8-10}.

The fact that the patient put out 10ml/kg/hr of urine on bypass indicates that there was adequate renal perfusion\textsuperscript{8,11}.

The Hct, pH and venous oxygen saturation were within acceptable limits post-bypass which indicates that the patient's oxygen carrying capacity remained adequate. This is another indicator of adequate tissue perfusion\textsuperscript{8,12-14}. The arterial oxygen saturation was 99.8 percent. This only proves that the oxygen carrying capacity of the hemoglobin was maximized; not that the oxygen content available for exchange at the tissue level was adequate. Therefore, the pH and the HCO\textsubscript{3} must be scrutinized. The final blood gas on bypass showed a pH of 7.34 with a pCO\textsubscript{2} of 45 and a HCO\textsubscript{3} of 23. These results demonstrate the adequacy of perfusion because the production of lactate resulting from anaerobic metabolism would have depressed the pH even further.

During the late 1980s interest was rekindled in this approach to pediatric perfusion\textsuperscript{8,10,13,16}. We have used this technique successfully on 10 pediatric patients weighing as little as 11 kg, including one Jehovah's Witness patient. Their defects varied from an atrial septal defect to a Tetralogy of Fallot.

Bloodless primes have a place in pediatric open heart surgery. We demonstrated that this technique can be safely performed as evidenced by an adequate post-bypass hematocrit and by the lack of a significant acidosis.

**References**