CASE REPORT

Extracorporeal Circulation with Venous Pump Return in a Patient with Sickle Cell Trait and Beta-Thalassemia Minor

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Abstract

The venous pump return has proven to be a safe and simple method for partial exchange transfusions in the patient with sickle cell disease. A partial exchange during the bypass procedure has eliminated the necessity of blood withdrawal and collection prior to surgery. The incorporation of an isolated cardiotomy reservoir as a holding chamber prevented the patient's blood and the blood in the extracorporeal circuit from premixing.

Introduction

The use of extracorporeal circulation in patients undergoing open heart procedures may cause various physiological changes. Complications may also arise in patients with sickle cell disease. During cardiopulmonary bypass, hypoxia, hypotension, alterations in temperature and acidemia may occur. Red cells in patients with sickle cell disease assume particular shape upon deoxygenation. The hemoglobin molecules are so altered that at a reduced oxygen tension they become stacked into intertwining strands which aggregate and sludge. Elongated and holly-leaf cells increase blood viscosity causing torpid flow, which cause further deoxygenation with eventual occlusion of small blood vessels. These changes can assume major importance in patients undergoing cardiopulmonary bypass.

Several cases have been reported with successful valve replacement and coronary artery disease in sickle cell patients. In these reported cases the hemoglobin S fractions were between 33 percent and 36 percent prior to partial blood exchange transfusion. The following is a case report of a patient who recently underwent surgery at our institution for triple coronary artery disease in whom the hemoglobin S fraction was 70 percent. Partial exchange transfusion was accomplished during the initial phase of cardiopulmonary bypass.

Case Report

The patient was a 53-year-old Black male with a history of an acute inferior wall myocardial infarction complicated by bradycardia and congestive heart failure. He was stabilized and discharged on digoxin 0.25mg daily, K-Tabs 2 TID, nitroglycerin 2.5mg daily and furosemide 40mg daily. In early January of 1981, he underwent a stress test which demonstrated significant ST-T changes in the anterior leads compatible with ischemia. He had only exercised 2 minutes and 15 seconds to Bruce Protocol Stage 1 prior to developing electrocardiographic (E.C.G.) changes which led to a cardiac catheterization. Past history indicated a gunshot wound to abdomen and unidentified surgery

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to the left hip without complications. The physical findings showed a blood pressure of 120/80 mm of mercury. The heart rate was 70/min with sinus rhythm. The jugular-venous pressure and carotid pulses were normal. The chest examination was clear to auscultation. Cardiac apex was palpated in the fifth intercostal space just medial to the mid-clavicular line; the impulse was within normal limits. First and second heart sounds were normal; no murmurs were evident. The abdominal findings were normal; spleen was not enlarged; urinalysis was normal. The peripheral pulses were present but reduced.

Summary of E.C.G. indicated sinus rhythm with mean ventricular axis of +15 degrees. Q waves in leads 2, 3 and AVF with ST-T changes indicated a remote inferior myocardial infarction. The diagnosis was significant coronary disease with major stenosis in the proximal left anterior descending artery, and complete occlusion of the proximal right coronary artery. Major stenosis was seen in the circumflex and posterior A-V groove arteries. Inferior hypokinesis secondary to remote inferior myocardial infarction was present and the ejection fraction was estimated at 70 percent. Cardiac output and indices, stroke volume and index were within normal limits. There was no evidence of shunting.

The admission hematology showed the following: white blood cells 8.5 x 10^6; red blood cells 5.0 x 10^6 with mild anemia (hemoglobin 12.5 gm/dl and hematocrit 38 percent). Red blood cell morphology on routine Wright smear revealed slight polychromatophilia with approximately 75 percent of the red cells showing nonspecific poikilocytosis with occasional teardrop poikilocytosis. There was +1 anisocytosis. Red blood cells indices were MVC 76, MCH 25.0, MCHC 33, RDW 17. Platelet count was 185,000. Differential white blood cells revealed 74 percent segmented neutrophils, 3 percent bands, 14 percent lymphocytes, 2 percent monocytes and 7 percent eosinophils. The reticulocyte count was 2.6; the sickle dex was positive. Hemoglobin electrophoresis revealed 70 percent hemoglobin "S" and approximately 20 percent hemoglobin "A". An acid elution was done for hemoglobin F which was 3.5 percent. A column chromatogram revealed hemoglobin A2 at 8.3 percent. Coagulation screening tests were normal. Red blood cell morphology on Wright stained preparation analyzed for sickle cell revealed approximately 1 sickle cell per 1000 red blood cells. Sodium metabisulfite preparation revealed 100 percent sickling after 15 minutes. Interpretation of these data classified the patient as having sickle cell trait with beta-thalassemia minor.

**Extracorporeal Circuit and Modifications.**

A Pemco unit hi-boy roller pump was used. The arterial line consisted of a 2-foot section of 3/4" I.D. latex tubing in the roller head. A section of 3/8" I.D. Tygon tubing 7 feet in length connected the roller to the patient. A section of 3/8" I.D. Tygon tubing 2 feet in length completed the circuit to the oxygenator. Sump lines consisted of 1/2" I.D. latex tubing in the roller heads. A 7-foot section of 3/16" I.D. Tygon tubing connected to the operating field, and a 2-foot section of 5/16" Tygon tubing connected to the cardiotomy reservoir with a Pall bypass filter in line. The venous return line consisted of a 7-foot section of 3/8" Tygon tubing connected to a 6" section 1/2" I.D. latex tubing to depulsate flow into the venous pump. A 2-foot section of 3/8" I.D. latex tubing ran through the venous pump roller head. A 2-foot section 3/8" Tygon tubing connected the venous pump to the oxygenator. The venous pump is routinely used in this institution as it has proven to afford greater control of venous return and venous pressures.

To effect the partial exchange transfusion, a modification to the venous line was incorporated. The modification (see Fig. 1) consisted of inserting a 3/8" I.D. "Y" type clear plastic connector into the Tygon tubing 8 inches above the venous pump head. The purpose for this modification was to incorporate an isolated cardiotomy reservoir to serve as a holding chamber for the patient's return blood. This cardiotomy was equipped with a short section of 3/16" I.D. Tygon tubing 3" in length to

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* Pemco, Inc., Cleveland, Ohio 44131.
* Kent Laboratories Tubing, Kent, Ohio, 44240
* Norton Plastics, Akron, Ohio 44309.
* H-1000, William Harvey, Santa Ana, California 92705.
* H-700, William Harvey, Santa Ana, California 92705.
* Pall Biomedical Products Corp., Glenn Cove, N.Y. 11542.
* Cobe Laboratories, Inc., Lakewood, Colorado 80215.
OXYGENATOR
VENOUS PUMP
RETURN
CARDIOTOMY WITH BY-PASS FILTER
ISOLATED CARDIOTOMY RESERVOIR
DRAIN OFF
VENOUS PUMP RETURN

FIGURE 1. Installation of isolated cardiotomy reservoir.

which a drain-off blood collection set\(^b\) was attached. The circuit was filled with 4 liters of lactated Ringer's solution. Pumps were started and a 5-minute pre-bypass rinse was applied to the system. The pumps were calibrated for occlusion. The venous line to the oxygenator was clamped and a rinse was applied to the isolated reservoir. Pumps were discontinued and the oxygenator was emptied.

The bubble oxygenator\(^d\) was then primed with 500 ml 10% Low Molecular Weight Dextran\(^1\), 0.9% sodium chloride\(^1\), 2 units (100cc/Unit) 25% normal serum albumin\(^1\), 500ml Normosol 'R' pH 7.4\(^1\) and 1 unit (250cc) packed cells. Oxygen flow of 1 liter/min was maintained in the oxygenator during priming.

**Bypass Technique**

Prior to the onset of bypass, gas flows were set at 7 liters/min \(\text{O}_2\) and 200 cc/min \(\text{CO}_2\). A mild hypothermia (32°C) was established. The venous line to the oxygenator was clamped. The arterial and venous pumps were started. A predetermined flow rate of 30cc/kg was held for approximately 3 minutes. Blood from the patient was shunted into the isolated cardiotomy reservoir. A total of approximately 2500cc was collected. The mean arterial pressure was maintained at 60 mm Hg without pressors. Blood loss from the oxygenator was replaced with a quick prime consisting of 1000ml Normosol 'R' pH 7.4 and 4 units (250cc/unit)

\(^a\) Fenwal Laboratories, Deerfield, Illinois 60015.
\(^b\) Abbott Hospital Products, North Chicago, Illinois 60064.
packed cells. Following collection of the patient's blood into the reservoir, the reservoir was clamped and normal cardiopulmonary circulation was instituted.

A flow rate of 50cc/kg or a total flow of 4900cc was maintained. The heart was stopped using a topical ice slush (4°C) and electrical fibrillation. Venous pressure was lowered via the venous return pump and the heart was emptied. The venous pressure was maintained in the negative pressure range allowing the surgeon to work on a decompressed heart without the necessity of a left ventricular decompression. The left internal mammary was anastomosed to the main circumflex artery, a saphenous vein graft to the distal right coronary artery and a saphenous vein graft to the anterior descending coronary artery. Twenty mg. of furosemide were administered via the oxygenator. A total of 240cc urine output was recorded. Arterial blood gases, hematocrit, and hemoglobin

### TABLE I
Hematology

<table>
<thead>
<tr>
<th></th>
<th>Pre-Induction</th>
<th>15' Bypass</th>
<th>1 Hr. Bypass</th>
<th>2 Hr. Bypass</th>
<th>Post-Pump</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hemoglobin (gm/100%)</td>
<td>11.0</td>
<td>9.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hb S electrophoresis</td>
<td>70% Hgb S</td>
<td>70%–80% Hgb S</td>
<td>40%</td>
<td>30%</td>
<td>20%</td>
</tr>
<tr>
<td></td>
<td>8.3% Hgb A2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3.5% Hgb F</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>18.2% Hgb A</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sickling in Arterial</td>
<td></td>
<td>100%</td>
<td>40%</td>
<td>30%</td>
<td>20%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>70% after 15' incubation in supersaturated sodium metabisulfite</td>
<td>100%</td>
<td>40%</td>
<td>30%</td>
<td>20%</td>
</tr>
<tr>
<td>Hb S cells sickled (%)</td>
<td>1 in 1000 on initial wet prep</td>
<td>1 in 1000</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Hb S cells sickled irreversibly</td>
<td>100% after 15 min. incubation in supersaturated sodium metabisulfite</td>
<td>80%</td>
<td>30%</td>
<td>20%</td>
<td>10%</td>
</tr>
<tr>
<td>Red Cells which contain Hb S</td>
<td>100%</td>
<td>100%</td>
<td>80%</td>
<td>50%</td>
<td>20%</td>
</tr>
</tbody>
</table>

### TABLE II
Laboratory Test Results (Arterial)

<table>
<thead>
<tr>
<th></th>
<th>Pre Induction</th>
<th>Induction</th>
<th>Pre-Pump</th>
<th>1st gas on bypass (15 minutes)</th>
<th>2nd gas (30°C) on bypass (30 minutes)</th>
<th>3rd gas (29.5°C) on bypass (60 minutes)</th>
<th>4th gas (34°C) on bypass (90 minutes)</th>
<th>5th gas (38°C) on bypass (128 minutes)</th>
<th>Post-pump</th>
<th>Recovery Room</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCO₂</td>
<td>40.5</td>
<td>30.4</td>
<td>29.2</td>
<td>34.4</td>
<td>30.9</td>
<td>30.8</td>
<td>28.1</td>
<td>33.3</td>
<td>37.4</td>
<td>36.2</td>
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<tr>
<td>PO₂</td>
<td>73.1</td>
<td>360.8</td>
<td>262.3</td>
<td>515.3</td>
<td>604</td>
<td>620.8</td>
<td>563</td>
<td>266.4</td>
<td>92.4</td>
<td>67.8</td>
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<tr>
<td>HCO₃</td>
<td>22.7</td>
<td>21.3</td>
<td>17.9</td>
<td>16.7</td>
<td>19.6</td>
<td>20.3</td>
<td>17.8</td>
<td>16.8</td>
<td>16.3</td>
<td>17.8</td>
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<tr>
<td>B.E.</td>
<td>-2.2</td>
<td>-1.2</td>
<td>-5.2</td>
<td>-9.3</td>
<td>-6.4</td>
<td>-5.8</td>
<td>-6.9</td>
<td>-7.6</td>
<td>-9.8</td>
<td>-8.3</td>
</tr>
<tr>
<td>SaO₂</td>
<td>90.5</td>
<td>95.5</td>
<td>95.3</td>
<td>96.7</td>
<td>96.8</td>
<td>99.9</td>
<td>96.6</td>
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<td>94.5</td>
<td>91.9</td>
</tr>
<tr>
<td>Hgb</td>
<td>11</td>
<td>11.1</td>
<td>11.9</td>
<td>7.3</td>
<td>6.4</td>
<td>9.2</td>
<td>7.4</td>
<td>7.2</td>
<td>9.0</td>
<td>13.1</td>
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<tr>
<td>Hct.</td>
<td>31.0</td>
<td>21.0</td>
<td>21.0</td>
<td>20.0</td>
<td>21.0</td>
<td>21.0</td>
<td>22.0</td>
<td>22.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urine</td>
<td>240 cc</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>
FIGURE 2. Pre-bypass.

FIGURE 3. Aliquot sample taken after 1.5 hours on bypass. Partial exchange transfusion using 4 units (250cc/unit). Washed packed cells and withdrawing 2.5 liters of patient's blood.

FIGURE 4. Post cardio-pulmonary bypass procedure. Final aliquot of blood revealed 20% sickling and 80% non-sickling after 15 minutes, incubation with sodium metabisulfite.

were recorded (Table II). Upon completion of revascularization, internal paddles were applied and the heart was defibrillated with one shock at 10 watt-seconds. No difficulties were encountered during the 128-minute bypass procedure. Mean arterial pressure was stable at 60 mmhg, the hematocrit level was constant at 22 percent, the hemoglobin level dropped slightly from a pre-bypass level of 11.0 gm percent to 9.0 gm percent post-pump. Blood loss from the oxygenator was replaced. A total of 780ml were added consisting of 530ml Normosol "R" pH 7.4 and 1 unit packed cells (250cc/unit). Prior to completion of definitive surgery the heat exchange temperature was reset to 40°C and the patient was rewarmed to 38°C esophageal. Flow rates were gradually reduced and bypass was discontinued. The patient was transfused with 600cc from the oxygenator and the excess perfusate was collected into blood transfer bags to be washed and used during the postoperative period.

The patient was monitored during cardiopulmonary bypass by analyzing aliquots of blood. The
monitoring procedure consisted of microscopic observation of wet preparations of the patient's blood, using cover slips, slides and supersaturated sodium metabisulfite. One-half drop of patient's blood was mixed with three drops sodium metabisulfite, mixed, cover slipped and sealed. An immediate determination was made by the pathologist to observe if any sickling was present. On the first aliquot of blood before bypass procedure and before partial transfusion, 100 percent of the patient's cells sickled after 15 minutes of incubation with a supersaturated sodium metabisulfite. An aliquot sample drawn after partial transfusion revealed approximately 30 percent sickle cells and 70 percent non-sickling red blood cells. At the end of cardiopulmonary bypass, the final aliquot revealed 20 percent sickling after 15 minutes of incubation and 80 percent non-sickling. All aliquots of blood were electrophoresed which confirmed presence of 70 percent hemoglobin "S" immediately before partial transfusion exchange and a reversal of this to at least 70 percent hemoglobin "A" after partial exchange (see Figs. 2, 3, 4). The patient continued to do well with hemoglobin electrophoresis and wet preparations showing 70 percent to 80 percent normal cells and 20 percent sickling cells. The patient was discharged approximately 2 weeks post-operatively and is back to full employment.

Acknowledgment

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References