Hepatic Resection Using Cardiopulmonary Bypass and Total Circulatory Arrest

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Abstract

Hepatoblastomas are the third most common malignant intra-abdominal tumor and are universally fatal without resection. Resections of these tumors are often difficult due to their size. Chemotherapy is frequently used to reduce the size of the tumor and allow resection. Hepatic resection is often complicated with excessive bleeding and with an attendant mortality of 10 to 30%.

Cardiopulmonary bypass with total circulatory arrest was used on three patients for hepatic resection. The extracorporeal circuit consisted of a membrane oxygenator and a pulsatile flow pump. Pulsatile flow was utilized for its advantageous effects on cooling and rewarming times. An average time of 13 minutes was needed to cool the patient to a rectal temperature of 17°C. Upon reaching this temperature, systemic circulation was stopped and the patient was exsanguinated into the extracorporeal circuit. During circulatory arrest, tumor resection was performed. Circulatory arrest time averaged 37 minutes. After resection was completed, the patients were rewarmed to 37°C with an average time of 27 minutes and were gradually weaned from cardiopulmonary bypass.

This technique allows tumor resection in a bloodless environment and free retraction without fear of diminished circulation. Also, blood usage is minimal and blood conservation can be optimized.

Materials and Methods

All patients had CT scans and arteriograms to evaluate tumor extension and arterial anatomy. If no contraindications, patients were typed and cross-matched for 10 units of whole blood, 2 units packed red blood cells, 10 units platelets, and 5 units fresh frozen plasma. In the operating room, two large upper extremity peripheral and one central venous catheters were placed. The radial artery was used for continuously monitoring blood pressure. Exploratory celiotomy was performed to determine resectability. The common bile duct, hepatic artery, and portal vein were isolated. The hepatic vein was examined and isolated if easily dissected.

The patients were then heparinized with 300 u/kg of beef lung heparin and placed on CPB via a median sternotomy following our normal infant/pediatric protocol. The extracorporeal circuit (EC) consisted of a membrane oxygenator and a roller pump on all patients. Priming components included fresh frozen plasma, packed red blood cells, and lactated Ringers. Heparin (2500 units/unit of blood), sodium bicarbonate (15 mEq/unit of blood), and calcium chloride (1.5 mm/ml of fresh frozen plasma) were given to adjust the priming solution. A right angled aortic cannula was placed in the ascending aorta for systemic blood flow. A single venous cannula was inserted directly into the right atrium for venous return. Pulsatile CPB was started and blood flow rates of 2.5 to 3.2 l/min/m² were established to cool the patient to an average temperature of 17°C using rectal and nasopharyngeal probes. CPB was then stopped and the patient exsanguinated into the EC. During TCA, partial hepatectomy was per-
formed in a bloodless field. After resection, the patient was retransfused and CPB was reinstated. The patients were rewarmed to 37°C and gradually weaned from CPB.

**Results**

All patients were successfully weaned from CPB and transported to the intensive care unit. Complete tumor resection was accomplished in all patients. Post CPB bleeding was a complication in the first patient only and this child was on heparin prior to surgery. An autotransfusion system was set up and utilized for only this patient. Use of blood and blood products were minimized due to this procedure. Post-operatively, persistent bile drainage was noted as a complication in two patients. One patient developed distal common bile stricture. These complications required additional surgery to drain the biliary abscesses and the biliary stricture required a Roux-en-y bypass. One patient has developed a recurrent tumor while two patients remain tumor free seven months after resection (Table 1).

**Discussion**

CPB with TCA provides a bloodless field for tumor resection. The surgeon is free to retract the liver without concerns of diminishing circulation and the tumor border can easily be identified. These advantages allow the surgeon to work under optimal conditions. In our experience, TCA which lasts 45 to 60 minutes with the patient at 17°C has no detectable adverse affects. This gives the surgeon ample operating time. However, if more TCA time is needed, a short period of reperfusion can be employed to allow additional time on TCA. If excessive bleeding is encountered, it can be managed effectively. Blood can either be salvaged by using an autotransfusion system or by bagging blood from the EC.

A membrane oxygenator was used for its advantageous effects on platelets and hemolysis and in the event of the necessity for a long pump run. Pulsatile flow is used for its advantageous effects on maintaining physiologic as well as peripheral perfusion. We see a more uniform correlation in nasopharyngeal and rectal temperatures which allows for shorter pump times. This benefit is appreciated in both cooling and rewarming stages (Table 2).

This technique was used on a fourth patient who had a Wilms tumor extending into the vena cava from the iliac vein into the right atrium. During TCA, a right nephrectomy and excision of the tumor extension within the inferior vena cava and the right atrium were performed. The patient tolerated this procedure well and currently is tumor free.

Previous reports of extensive hepatic tumor resection have resulted in a significant mortality of 10 to 30%. These deaths were primarily due to hemorrhage.8 The use of CPB with TCA has allowed the surgeon to operate in a bloodless field with complete visualization of the tumor borders, as well as to be able to manipulate the liver to control caval vessels without compromising venous flow. Post resection

<table>
<thead>
<tr>
<th>Case #</th>
<th>Type of Resection</th>
<th>Pre-Op Chemotherapy</th>
<th>Intra-Op Blood Usage</th>
<th>Post-Op Blood Usage (3 day)</th>
<th>Post-Op Complications</th>
<th>Post-Op Hospitalization (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1*</td>
<td>Trisegmentectomy</td>
<td>Yes</td>
<td>7 u WB 6 u PC 7 u Plat 1285cc FFP</td>
<td>400cc FFP</td>
<td>Bile fistula</td>
<td>39</td>
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<tr>
<td>2</td>
<td>Left hepatic lobectomy</td>
<td>Yes</td>
<td>9 u WB 2 u PC 14 u Plat 690cc FFP 2 u Cryo</td>
<td>940cc FFP 1 u PC</td>
<td>Bile fistula</td>
<td>41</td>
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<tr>
<td>3</td>
<td>Trisegmentectomy</td>
<td>No</td>
<td>4 u PC 1 u WB 1100cc FFP</td>
<td>350cc FFP</td>
<td>Distal bile duct stricture</td>
<td>21</td>
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<tr>
<td>4</td>
<td>Right nephrectomy tumor resection in IVC &amp; right atrium</td>
<td>Yes</td>
<td>4 u PC 150cc FFP 10 u Plat</td>
<td>150cc FFP</td>
<td></td>
<td>6</td>
</tr>
</tbody>
</table>

*Patient on heparin prior to surgery, cell saver used
Legend: WB = whole blood, PC = packed cells, Plat = platelets, FFP = fresh frozen plasma, Cryo = cryoprecipitate
bleeding is easily compensated for by transfusion through the pump until the surgeon can gain control. Our experience utilizing CPB with TCA in infants with congenital heart disease surgery facilitates the incorporation of this technique for major hepatic resections.

Table 2

<table>
<thead>
<tr>
<th>Case #</th>
<th>Cooling Time (mins)</th>
<th>Rewarming Time (mins)</th>
<th>Total CPB Time (mins)</th>
<th>TCA Time (mins)</th>
<th>Wt. (kg)</th>
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<tbody>
<tr>
<td>1</td>
<td>13</td>
<td>24</td>
<td>37</td>
<td>36</td>
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<td>21</td>
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<td>Average</td>
<td>14.5</td>
<td>27</td>
<td>41.5</td>
<td>37</td>
<td>12.1</td>
</tr>
</tbody>
</table>

References


Question from the Audience

Question—Bruce Fuller: Do you use any decadron or penathol before arrest?
Answer: The patients are pre-treated with dilantin and steroids. All patients are.