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The Use of Profound Hypothermia and Circulatory Arrest for Hepatic Lobectomy in Infancy

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Primary hepatic tumors are uncommon,1 but most are malignant,2 and their onset usually occurs prior to the age of 2 years.3 The lethal course without surgical treatment necessitates prompt therapy, but results have been discouraging, with one series having a two-year survival rate of 10 per cent and a five-year survival rate of 0.4 The surgical technique of right hepatic lobectomy in children has been well described in the surgical literature,5 but several unusual features of this procedure, dictated by the anatomy of the liver and the principles of cancer surgery, need to be presented to permit understanding of the rationale of our approach to this particular case.

In a procedure for carcinoma of the right hepatic lobe, tapes are placed loosely around the portal vein, hepatic artery, and inferior vena cava (inferior to the right atrium and superior to the renal veins) for possible flow occlusion, to prevent inadvertent tumor and/or air emboli, and to control hemorrhage. With the aid of moderate hypothermia (to 32°C), the total blood supply of the liver may be interrupted for as long as 15 minutes for dissection. In view of the aggressive measures currently advocated,5 which have successfully negotiated only the immediate operative period, the authors felt that yet more radical steps were indicated to improve the miserable long-term prognosis of the disease. The following is a case report of a right hepatic lobectomy performed on a 10-week-old infant using cardiopulmonary bypass, profound hypothermia, and circulatory arrest.

REPORT OF A CASE

A 10-week-old 5.6-kg female infant was admitted to the hospital for hemihepatectomy for probable hepatoblastoma, diagnosed by angiogram while she was anesthetized with a nitrous oxide–oxygen–relaxant technique. Preoperative laboratory data were all within normal limits.

The patient was unpremedicated and was anesthetized with ketamine, 30 mg, im; pancuronium bromide, 0.6 mg, iv, was given; the trachea was orally intubated, and she was mechanically ventilated with humidified 60 per cent nitrous oxide and 40 per cent oxygen. Catheters were placed in the left radial artery and external jugular vein, and esophageal and rectal temperatures. EEG and ENG were recorded. Surface cooling was then instituted using a combination of ice and a cooling blanket. Minute ventilation was reduced, and carbon dioxide (to as much as 5 per cent) was added to the inspired gas mixture, as dictated by serial arterial blood gases. When the rectal temperature reached 28°C (26.8°C esophageal), surface cooling was discontinued and exploratory laparotomy was begun. The tumor was found to involve only the right hepatic lobe; the sternum was then opened, heparin administered, and cardiopulmonary bypass was instituted for 18 minutes to achieve further cooling to a rectal temperature of 18°C (17°C esophageal). At this temperature the child’s blood was drained into the pump and bypass was discontinued. Surgical resection required 32 minutes, and bypass was resumed for 42 minutes to return the temperature to 34°C (rectally 35°C esophageal). During hypothermia anesthetic requirements were negligible. During the rewarming process a central venous pressure line was placed via the superior vena cava into the right atrium. At the termination of bypass and after protamine had been administered, the central venous pressure trace was noticed to be of poor quality. The line was therefore aspirated and flushed clear. Immediately following this procedure, the patient’s condition deteriorated, with profound hypotension, and myocardial cyanosis was noticed by the surgeon. The presumptive diagnosis of intracranial arterial air was made. Aspiration from the central venous pressure line revealed highly saturated blood, strongly suggesting inadvertent left atrial

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catheter placement. The catheter was withdrawn 1 cm, and repeat aspiration then revealed unsaturated right atrial blood. Simultaneously, heparin was administered and cardiopulmonary bypass was re instituted for a further 30 minutes. Subsequent return to normal cardiac action was uneventful. At the termination of the procedure the infant was transferred to the intensive care unit and continuous mechanical ventilation was begun. Because she had received heparin and protamine in rapid sequence, with an intervening period on bypass, the patient left the operating room with suspected clotting abnormalities; eight hours later she was re-explored for excessive bleeding. No specific bleeding site could be identified. The patient was returned to the intensive care unit and remained mechanically ventilated until she was extubated on the third postoperative day. Pathologic diagnosis of the tumor was hemangioendothelioma, for which the resection should be completely curative. She was discharged from the hospital three weeks after the procedure and has since done well.

**DISCUSSION**

In their review of the world’s literature of hepatic tumors in children, Ishak and Glunz\(^6\) found only 20 two-year survivors among approximately 200 children with hepatic tumors. In light of this poor prognosis, we approached this problem with a view toward improving long-term results through superior operating conditions and strict attention to the principles of the cancer surgery, i.e., total en-bloc excision. The precedent for the use of cardiopulmonary bypass with profound hypothermia and circulatory arrest for noncardiac procedures was set at the Mayo Clinic, in the report of two patients who underwent intracranial surgery using this technique.\(^7\) We chose the combination of surface and bypass cooling to achieve hypothermia because this method leads to more even cooling, better precirculatory arrest oxygenation, and superior cardiac and hepatic function during rewarming.\(^8\) We added CO\(_2\) to the inspired gas to prevent alkalosis and attendant shifts in the oxyhemoglobin curve. It was our opinion that the advantages of prolonged dissection time (as long as 70 minutes at 18 C rectally)\(^8\) in a bloodless field, with the ability to manipulate the liver without concern for tumor emboli, justified this extraordinary step, and that this represented a logical extension of the technique of vascular isolation and hypothermic perfusion reported by Fornter et al.\(^9\) Serum lactate increased to a peak of 7.3 mmol immediately after arrest and quickly decreased to 6.2 mmol for the remainder of the procedure. These values, as well as an average base excess of −5 mmol, are consistent with the values reported to occur with profound hypothermia and circulatory arrest,\(^9\) indicating that minimal amounts of normal liver were removed. The air entrainment via the central venous pressure line was inexcusable, particularly in view of the high incidence of patent foramen ovale before the age of 3 months.\(^10\) This led to re-heparinization and an extension of the time on bypass, which we felt was largely responsible for the re-exploration eight hours after the initial procedure. One of the motivating factors for our choice of this approach was eliminated with the much less malignant diagnosis of hemangioendothelioma; however, despite this, and the technical error with the central venous pressure line, we present this approach as having potential merit for the management of hepatic tumors in children.

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