Anesthesiology
77:382–383, 1992

The Institution of Veno-venobypass by Peripheral Cannulation under Emergent Intraoperative Conditions

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Experience from orthotopic liver transplantation has demonstrated the adverse hemodynamic consequences of suprahepatic inferior vena cava cross-clamping,[1] as well as the utility of centrifugal pump–assisted veno-venobypass in avoiding these complications.[2] Specifically, venous return, and as a result, cardiac output, is maintained while avoiding visceral engorgement, excessive bleeding, and the accumulation of acid metabolites. Veno-venobypass has also been used for patients undergoing dissection of the retrohepatic inferior vena cava for renal cell carcinoma.[3–5] Cannulation for bypass in these instances was accomplished by thoracotomy to access the right atrium and by femoral vein cutdown. Current practice in our institution includes participation of the anesthesia team in the percutaneous placement of cannulae for bypass and in the management of pump flow during routine orthotopic liver transplantation. This experience was invaluable in the following case, wherein the emergent implementation of veno-venobypass by peripheral cannulation was lifesaving during an hepatic resection for metastatic tumor.

CASE REPORT

A 60-yr-old woman with a history of hypertension was scheduled to undergo a right hepatic lobectomy for a solitary ovarian metastasis. She had undergone a total abdominal hysterectomy and bilateral salpingooophorectomy for an ovarian granulosa cell tumor 13 yr previously.

The patient was brought to the operating room, and a radial arterial catheter, two peripheral (18-G), and a 14-G and an 8.5-Fr internal jugular intravenous cannula were inserted. Anesthesia was induced with fentanyl, midazolam, and thiamylal; the trachea was intubated; and anesthesia was maintained with fentanyl, enflurane, and pancuronium. The patient remained hemodynamically stable throughout the initial aspects of the procedure. Exploration revealed a large mass located posteriorly in the right hepatic lobe with no evidence of extrahepatic disease.

During dissection of the right hepatic vein, retraction of the large tumor mass distorted the anatomy, leading to inadvertent complete transection of the suprahepatic inferior vena cava. Inadequate control of the massive hemorrhage from the right hepatic vein led to profound hypotension. During the next 2.5 h, complete control of hemorrhage was obtained with occlusion of the proximal and distal vena cava and hepatic veins. During this period, the patient received 30 units of blood and required an epinephrine infusion of 0.5 $\mu g \cdot kg^{-1} \cdot min^{-1}$ to maintain systolic blood pressures greater than 60 mmHg. As a result, her heart rate increased to >120 beats per min with resultant 5-mm ST-segment depressions in ECG leads II and V5. A persistent metabolic acidosis (base deficit of 11) developed, which was resistant to 850 mEq of sodium bicarbonate. Anuria developed at this time; dopamine was infused, and furosemide and mannitol were administered.

Exposure of the surgical field had become increasingly difficult due to visceral distention. The right hepatic lobectomy was completed; however, it was apparent that reconstruction of the vena cava would be necessary, but hemodynamic instability and massive venous congestion appeared to make this impossible. At this time a right antecubital vein was cannulated with an 8.5-Fr cannula using a modified Seldinger technique. An 8.5-Fr cannula also was placed in the left femoral vein by surgical cutdown. Using a Biomedicus centrifugal pump (Biomedicus, Eden Prairie, MN), veno-venobypass was initiated with the antecubital cannula accepting pump outflow and the femoral cannula supplying inflow. Flow rate was begun at 0.74 l/min and increased to 1.0–1.5 l/min; heparin was not administered. During the bypass period hemodynamic stability was restored, with an 80% reduction in epinephrine requirements. The tachycardia resolved along with the ST-segment depression. Urine output resumed shortly after bypass was begun. Hemoglobin and intravascular volume were replenished; minimal transfusions were required throughout the remainder of the case. During the period of veno-venobypass, an inferior vena cava–right atrial shunt was constructed using an 18-mm ringed Gortex graft. At the completion of the vascular reconstruction, hemostasis was achieved, and the abdomen was closed using a Marlex mesh necessitated by residual intestinal distention.

The patient's condition continued to improve in the immediate postoperative period. There was no evidence of a myocardial infarction; renal function never appeared to be impaired; and the patient remained neurologically intact. She was returned to the operating room on postoperative day 7 for removal of the Marlex mesh and primary closure of the abdomen. Although the patient required prolonged tracheal intubation and respiratory support, she suffered no other postoperative complications and was discharged home on postoperative day 46.

DISCUSSION

The use of a veno-venobypass system during the anhepatic phase has virtually revolutionized orthotopic liver

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Received from the Johns Hopkins Hospital 600 N. Wolfe Street Baltimore, Maryland. Accepted for publication March 23, 1992.

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Key words: Surgery, hepatic: veno-venobypass.

transplantation. Prior to the reports of Shaw *et al.*[6] and Griffith *et al.*[7] in 1984, the anhepatic phase was marked by abdominal venous engorgement with massive blood loss and metabolic derangements. Without bypass, only a 60–90-min period of venous occlusion was tolerated by most patients.[6]

Two reports suggested the routine use of veno-venobypass in liver transplantation. Griffith *et al.* described a veno-venobypass system using a Biomedicus pump that did not require systemic administration of heparin.[7] Shaw *et al.*[6] then described the use of this system in a series of 28 patients. Hemodynamic parameters were preserved during the anhepatic phase with a decrease in systemic oxygen extraction. Cardiac index decreased 22% compared to 50% in a nonbypass group. Furthermore, the bypass group required less blood intraoperatively and demonstrated better postoperative renal function and better survival.[6] Although some controversy still surrounds the routine use of bypass during liver transplantation,[8] the hemodynamic, metabolic, and technical advantages makes this system attractive.

Aside from its use in orthotopic liver transplantation, venobypass has been used as an aid in other retrohepatic vena cava surgery. Attwood *et al.*, [3] David *et al.*, [4] and Janosko *et al.*[5] separately reported the use of venoatrial bypass using a Biomedicus pump during resection of renal carcinoma invading the vena cava. In each of these cases, the patients received heparin prior to institution of venobypass. The suprahepatic vena cava was clamped, and bypass was begun. David *et al.*[4] reported the use of pump flows of 1.3–2 l/min in order to maintain right atrial pressure of 5–8 mmHg. Janosko *et al.*[5] used the pump as a means to recirculate extravasated blood and as a means to rewarm the patient by interposition of an oxygenator circuit. In each of these reports, venobypass was extolled as a means of providing a superior operative field while maintaining adequate venous return. Veno-venobypass is not without its own complications, such as mechanical malfunction, thrombosis, and air embolism.[9]

To expedite initiation of veno-venobypass in routine orthotopic liver transplants, we have developed techniques that include the percutaneous placement of 8.5-Fr cannulae for venobypass outflow to the proximal circulation, and occasionally for pump inflow *via* the femoral vein, by the anesthesia team before surgery. This team then assists in the subsequent management of bypass parameters. Based on this experience, in the above case the anesthesiologists placed the outflow cannula and managed veno-venobypass in conjunction with the perfusion technologist during a period of massive hemorrhage. Because of the proximity of the femoral circulation to the surgical field, the femoral vein was cannulated by the surgical staff using a cutdown technique. Up to 1.5-l/min flow was attained using the two 8.5-Fr catheters; thus, heparin administration was not required.

The case we report is unique in a number of aspects. Veno-venobypass was instituted as an emergent intervention when intraoperative events dictated that continued suprahepatic inferior vena cava obstruction was life-threatening. A surgical approach to more central venous structures in an effort to establish more traditional veno-venobypass access was severely limited by the massive ongoing hemorrhage; thus, peripheral cannulation was the sole option. The anesthesiologists' assessment of the adequacy of cardiac output and volume status in collaboration with the surgeons' evaluation of the operative field contributed to the rational management of veno-venobypass. After the institution of bypass renal function returned, ongoing blood loss decreased; visceral distention was diminished; and hemodynamic stability was restored.

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