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Percutaneous technique for venovenous bypass including a heat exchanger is safe and reliable in liver transplantation

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Abstract We have introduced and evaluated several modifications of the conventional venovenous bypass (VVBP) in 29 adult patients undergoing liver transplantation (OLT). A percutaneous technique for insertion of a jugular venous return cannula and a femoral vein cannula was applied. The inferior mesenteric vein (IMV) was used for splanchnic decompression, which facilitated dissection of the recipient liver and allowed portal anastomosis to be performed without disconnecting the portal bypass. A heat exchanger was introduced into the bypass circuit to prevent heat loss. The percutaneous technique prevented complications related to dissection in the axilla and groin. Hemodynamic characteristics corresponded to those found using the traditional technique. Complications related to the VVBP were seen in only one patient in whom the femoral catheter was accidentally introduced into the femoral artery. We conclude that percutaneous cannulas, use of the IMV for splanchnic decompression and the introduction of a heat exchanger offer significant benefits and that they are safe and reliable.

Key words Liver transplantation, percutaneous bypass · Venovenous bypass, percutaneous, liver transplantation

Introduction

Venovenous bypass (VVBP) was introduced in patients undergoing orthotopic liver transplantation (OLT) to prevent venous stasis in the lower part of the body and splanchnic venous pooling during the anhepatic phase. The technique has been improved and refined several times since it was first applied during the earliest attempts at human OLT in 1963 [37]. It is now recognized as an integral part of a standard OLT [21], although some have questioned its routine use [3, 14, 18, 39, 40]. Application of VVBP preserves renal function [32, 39], decreases peroperative blood loss [32], and reduces third space fluid losses, visceral edema, and splanchnic venous pooling [21, 32]. It also allows hepatectomy and graft implantation under more hemodynamically stable conditions.

The technique of establishing VVBP has varied. Traditionally, catheters have been inserted into the saphenous and axillary veins via a cut-down technique. The main portal vein has been used for splanchnic blood drainage after dissection of the hepatoduodenal ligament [12, 32]. Heat exchangers have not been used routinely as they may represent a clotting hazard in nonheparinized systems [24]. Both heparinized and nonheparinized systems have been used in closed circuits without venous reservoirs driven by centrifugal pumps [6, 12, 24].

Refinements of the classical VVBP procedure have been presented. The use of a heat exchanger has been reported to prevent hypothermia [5], and cannulation of the IMV has allowed early decompression of the splanchnic venous bed and permitted portal anastomosis without interruption of bypass [11, 13, 34]. Percutaneous techniques for insertion of the femoral cannula and the return catheter, thereby preventing dissection in the groin and axilla, have also been reported [4, 22, 26, 29, 30, 36].

All OLTs in our institution were carried out without bypass until the VVBP system described here was introduced in 1993. The aim of this study was to evaluate our experience with VVBP using several of these modifications incorporated into a functioning system.

Materials and methods

Patients

Twenty-nine consecutive patients undergoing primary liver transplantation (16 women and 13 men, mean age 42 years, range 20–58 years) at Rikshospitalet, The National Hospital, in Oslo, Norway, were studied (Table 1). All patients gave their informed consent to participate in the study, which met the ethical standards of the 1964 Declaration of Helsinki. The indications for transplantation and patient characteristics are listed in Table 1.

Veno-venous bypass

A Bio-Medicus Femoral Arterial kit (15 Fr/18-cm straight tip with holes; Medtronic, USA) was inserted percutaneously into the right internal jugular vein by the anesthesiologist preoperatively using Seldinger's technique. The cannula was continuously flushed with saline until the start of VVBP. For insertion of the femoral vein cannula, the inguinal region was scrubbed and draped preoperatively. After laparatomy and trial dissection of the liver, a Bio-Medicus Femoral Venous kit (17 Fr/50-cm straight tip cannula; Medtronic, USA) was introduced percutaneously into the femoral vein and advanced into the inferior vena cava by an anesthesiologist using Seldinger's technique, as previously reported by Ozaki and coworkers [23]. In 21 patients the IMV was cannulated with a Bio-Medicus Pediatric Venous Cannula (14 Fr/12-cm straight tip; Medtronic, USA), while direct cannulation of the portal vein was used for splanchnic VVBP in 8 patients using a 29 Fr/50-cm straight tip Bio-Medicus Femoral Venous Cannula (Medtronic, USA).

The bypass circuit consisted of a model CB 4649 custom pack liver set (3/8" tubing, Medtronic, USA) with a Biomedicus BP-80 centrifugal pump (Medtronic, USA) and a D 720 Helios-A CP heat exchanger (Dideco, Mirandola, Italy). The circuit was primed with 440 cc of 10 % albumin at room temperature. In five of the patients, the heparin-coated model CB 4649 custom pack liver set (Medtronic, USA) with D 720 Helios-A CP heat exchanger (Dideco, Mirandola, Italy) and cannulas were used as part of an ongoing, prospective, randomized study. In the other 24 patients, nonheparinized cannulas, circuits, and heat exchangers were used.

Hemodynamic data (heart rate, mean arterial pressure, central venous pressure) and body (rectal) temperature were continuously recorded. For this study, data obtained before the start of VVBP, 1 h after the start of the VVBP, and 5 min after discontinuation of VVBP will be presented.

Table 1 Indications for OLT and patient characteristics

Indication	*n*	F	M	Age (years)
Sclerosing cholangitis	11	5	6	21–58
Primary biliary cirrhosis	8	7	1	40–58
Alcoholic cirrhosis	3	0	3	52–58
Autoimmune cirrhosis	2	1	1	46–55
Hepatocellular carcinoma	2	2	0	15–22
Budd-Chiari disease	1	1	0	20
Posthepatitic cirrhosis	1	0	1	40
Acute hepatic failure	1	0	1	20
	29	16	13	Mean = 42

Statistical analysis

Descriptive statistics are given as medians with 95 % confidence intervals (95 % CI) for the medians. Differences between hemodynamic parameters and body temperature values at specified time points were compared using a repeated measures ANOVA. Individual means were compared with the Student-Newman-Keuls multiple comparison procedure. P values less than 0.05 were considered statistically significant.

Results

The duration of VVBP was 125 (95 % CI 100–152; range 66–305) min. The entire length of the surgical procedure was 435 (95 % CI 388–540; range 290–658) min.

Systemic VVBP flow before inclusion of the IMV limb of the circuit was 1.9 (95 % CI 1.7–2.4; range 1.3–3.0) l/min. Opening of the splanchnic bypass through the IMV resulted in a 29 % flow increase to 2.7 (95 % CI 2.5–3.0; range 1.7–3.0 l/min; $P < 0.05$). The pump rate was 2324 (95 % CI 2073–2538; range 1485–3386) rpm.

A single complication related to the technique was an accidental introduction of the femoral cannula into the femoral artery. This incident was recognized before the start of VVBP and an immediate artery repair was carried out, followed by introduction of the venous cannula through the saphenous vein. Otherwise, all insertions of the cannulas were uneventful and no significant complications, technical or other, related to cannulation were found. One patient (UNOS stage III) died peroperatively in the reperfusion phase due to therapy-resistant cardiovascular collapse.

Mean arterial pressure (MAP) was stable during VVBP but decreased by 13 % after VVBP was discontinued (Table 2). No variation in heart rate was found (Table 2). Central venous pressure (CVP) decreased through the 1st hour of VVBP (12–9 mm Hg; $P < 0.05$) but rose towards the end of VVBP (9–11 mm Hg; $P < 0.05$; Table 2).

Table 2 Hemodynamic data and body temperature during OLT. Values represent the median with 95 % confidence intervals

Variable	Start of bypass	1 hour of bypass	End of bypass
Heart rate (bpm)	105 (95–110)	105 (95–110)	105 (95–110)
Mean arterial pressure (mm Hg)	80 (73–80)	82 (77–90)	70 (63–75)*,***
Central venous pressure (mm Hg)	12 (11–14)	9 (7–12)**	11 (9–14)***
Temperature (°C)	36.5 (36.4–37.0)	37.3 (37.0–37.5)**	37.0 (36.8–37.0)*

* $P < 0.05$ for start of bypass vs end of bypass; ** $P < 0.05$ for start of bypass vs 1 h of bypass; ** $P < 0.05$ for 1 hour of bypass vs end of bypass

Table 3 Blood product requirements during OLT. Values represent the median with 95 % confidence intervals

Packed red blood cells (units of 250 cc)	10 (7–23)
Fresh frozen plasma (Octaplas; units of 200 cc)	9 (7–13)
Thrombocyte concentrate (units of 250 cc from one donor)	8 (0–8)
Albumin 4 % (cc)	2700 (1700–4250)
Albumin 20 % (cc)	1500 (100–200)

The heat exchanger maintained good control of body temperature (BT) during the VVBP procedure. In fact a small increase in BT was found after 1 h of VVBP (36.5 °C–37.3 °C; $P < 0.05$). This level of BT was maintained towards the end of bypass (Table 2).

Peroperative use of red blood cells, fresh frozen plasma, and donor thrombocyte concentrate was 10 units (95 % CI 7–23; range 3–93), 9 units (95 % CI 7–13; range 0–54), and 8 units (95 % CI 0–8; range 0–24), respectively (Table 3).

Discussion

In this study, we evaluated venovenous bypass in OLT using a percutaneous technique for femoral and internal jugular cannula insertion, and early cannulation of the inferior mesenteric or portal vein for splanchnic decompression using an in-line heat exchanger.

Preoperative insertion of the internal jugular return cannula during induction of anesthesia spared the surgeon the procedure of establishing venous return during OLT. Using the internal jugular vein for venous return made it possible to avoid 90° left arm abduction throughout OLT, something that has been shown to give rise to neurological complications [7, 19, 20]. Furthermore, it prevented surgical preparation of the axillary region, which may result in injuries to the axillary artery, the brachial plexus, and the lymphatic structures [4, 23, 30, 33]. The jugular return cannula also facilitates rapid infusion during the operation, should such be required. At the time VVBP was started, the caval outflow cannula was introduced by the anesthesiologist through puncture of the femoral vein, thus preventing dissection in the inguinal region. Percutaneous cannula introduction was found to be a safe procedure for introduction of a 17 Fr catheter, though the accidental puncture of the femoral artery was of concern. However, this complication was not related to the size or introduction procedure of the catheter itself. The risk of using the percutaneous technique should be equal to the risk of iatrogenic vascular trauma in relation to the introduction of central venous catheters in general, and this risk is low [28, 35, 38].

The IMV was used for the splanchnic outflow cannula, as reported earlier by others [11, 13]. Splanchnic decompression was therefore achieved before hilar dissection, which facilitated dissection and hemostasis in patients with previous surgery in the hilar region or in patients with portal hypertension. An additional advantage was that the portal anastomosis could be fashioned without discontinuing the splanchnic bypass. This prevents venous pooling at any time during the operative procedure. The bypass flow using the IMV was comparable to flow rates of standard VVBP [11, 13]. No technical complications related to this procedure were noted. In spite of the clear benefits of this procedure, one must bear in mind that it creates an additional dissection plane and that this has possible consequences, such as bleeding and lymphatic leakage. In 8 of the 29 patients, however, the portal vein had to be used for the VVBP because of prior surgery affecting the IMV.

Previous reports have assessed the problem of temperature changes and the risk of hypothermia in OLT [5, 24, 25]. In our study, BT was stable and maintained within narrow limits during VVBP. BT was 0.5 °C higher at the time VVBP was discontinued than at the start (Table 2). Fear of blood clotting and subsequent embolus formation has prevented an in-line heat exchanger from being widely used in OLT. To our knowledge, only one previous report applied such a means of temperature regulation [5]. At the end of VVBP, the splanchnic and femoral limb of the circuit is disconnected first, and most of what is present in the circuit is returned through the internal jugular vein. During this procedure, the catheters and all parts of the circuits, including the heat exchangers, were inspected. We found no evidence of clotting problems in the extracorporeal circuits in any of the 29 patients, irrespective of whether heparinized circuits were used (5 patients) or not (24 patients). Both heparinized and nonheparinized systems are in use at our center as part of an ongoing, prospective, randomized study to evaluate the possible pathophysiological benefits of heparinized circuits.

The start of VVBP did not lead to significant changes in MAP, which was unchanged after 1 h of VVBP (Table 2). The 13% reduction in MAP after VVBP observed in the reperfusion phase corresponds with hemodynamic changes previously reported in this phase of OLT [1, 2, 8, 16, 27, 31]. The use of VVBP might lead to a decrease in heart rate, possibly due to the decrease in body temperature that occurs if a heat exchanger is not used [24]. Furthermore, the transient cardiovascular changes seen at the initiation of VVBP may be due to cold volume loading of the heart and hemodilution, which is known to affect the coronary circulation [24]. We found no differences in heart rate during the VVBP procedure (Table 2). This indicates that hemodynamic changes related to heat loss can be prevented when a heat exchanger is integrated into the system.

In most previous studies, CVP was generally not affected by the initiation of VVBP [11, 15, 30, 32]. In this study, CVP was reduced from 12 mm Hg at the start of VVBP to 9 mm Hg after 1 h of VVBP. However, CVP returned to baseline values after VVBP was discontinued (Table 2). Conclusively, hemodynamic parameters did not differ from conventional bypass using open surgical technique.

Blood usage during OLT has gradually decreased over the years, probably due to improved surgical techniques with the use of blood salvage procedures and better management of coagulation [25]. Table 3 shows the median number of red blood, fresh frozen plasma, thrombocyte concentrate, and albumin used during the operative procedures. The blood usage in this study did not differ significantly from reports of others [9, 10, 17, 25].

VVBP was introduced as a routine procedure in adult patients undergoing liver transplantation at our center in 1993. At that time, refinements of elements of the VVBP concept had been described [4, 5, 11, 13, 22, 26, 29, 30, 34, 36]. We designed a modified set-up that prevents complications related to dissection in the groin and the axilla. It is also important that parts of the procedure are done preoperatively in order to save operating time. The problems related to heat loss were prevented by the introduction of a heat exchanger into the extracorporeal circuit, which kept BT within narrow and normal limits. Finally, cannulation of the IMV for splanchnic decompression permitted early initiation of VVBP and allowed suturing of the portal anastomosis without discontinuation of the splanchnic bypass arm.

We are of the opinion that this modified VVBP procedure has several advantages over the traditional technique as hazards related to the open surgical technique are avoided. No complications affecting patient outcome have thus far been recorded.

References

1. Aggarwal S, Kang Y, Freeman JA, Fortunato FL, Pinsky MR (1987) Postreperfusion syndrome: cardiovascular collapse following hepatic reperfusion during liver transplantation. Transplant Proc 19: 54–55
2. Aggarwal S, Kang Y, Freeman J, De Wolf AM, Begliomini B (1989) Is there a post-reperfusion syndrome? Transplant Proc 21: 3497–3499
3. Beltran J, Taura P, Grande L, Garcia-Valdecasas JC, Rimola A, Cugat E (1993) Venovenous bypass and liver transplantation (letter; comment). Anesth Analg 77: 642
4. Benedetti E, Pirenne J, Troppmann C, Hakim N, Gruessner R, Cochrane R, Irmiter R, Payne W, Belani K (1995) A percutaneous technique for venous return cannula insertion for veno-venous bypass in hepatic transplantation. Transplantation 59: 789–791
5. Butler KT, Raskin SA, Whisennand HH, Lowell WR, Gay JR, Cornelius GF (1991) Use of a heat exchanger in liver transplantation. Perfusion 6: 279
6. Denmark SW, Shaw BW, Starzl TE, Griffith BP (1983) Veno-venous bypass without systemic anticoagulation in canine and human liver transplantation. Surg For 34: 380
7. Dhuner KG (1950) Nerve injuries following operations: a survey of cases occurring during a six-year period. Anesthesiology 11: 289
8. Estrin JA, Belani KG, Ascher NL, Lura D, Payne W, Najarian JS (1989) Hemodynamic changes on clamping and unclamping of major vessels during liver transplantation. Transplant Proc 21: 3500–3505
9. Gerlach H, Rossaint R, Bechstein WO, Blumhardt G, Neuhaus P, Falke K (1993) "Goal-directed" transfusion management leads to distinct reduction of fluid requirement in liver transplantation. Semin Thromb Hemost 19: 282
10. Gerlach H, Slama KJ, Bechstein WO, Lohmann R, Hintz G, Abraham K, Neuhaus P, Falke K (1993) Retrospective statistical analysis of coagulation parameters after 250 liver transplantations. Semin Thromb Hemost 19: 223–232
11. Grande L, Cugat E, Garcia-Valdecasas JC, Rimola A, Taura P, Beltran J, Fuster J, Lacy AM, Sala X, Gonzalez FX, et al (1993) Cannulation of the inferior mesenteric vein for veno-venous bypass in human liver transplantation: a reliable procedure? Transplant Proc 25: 1896–1898

12. Griffith BP, Shaw BWJ, Hardesty RL, Shunzaburo I, Bahnson HT, Starzl TE (1985) Veno-venous bypass without systemic anticoagulation for transplantation of the human liver. Surg Gynecol Obstet 160: 271
13. Jabbour N, Todo S, Selby R, Starzl TE (1995) Venovenous bypass using inferior mesenteric vein for portal decompression during orthotopic hepatic transplantation. J Am Coll Surg 180: 100
14. Johnson MW, Powelson JA, Auchincloss HJ, Delmonico FL, Cosimi AB (1996) Selective use of veno-venous bypass in orthotopic liver transplantation. Clin Transplant 10: 181–185
15. Jugan E, Albaladejo P, Jayais P, Ecoffey C (1992) The failure of venovenous bypass to prevent graft liver postreperfusion syndrome. Transplantation 54: 81–84
16. Kang YG, Freeman JA, Aggarwal S, DeWolf AM (1989) Hemodynamic instability during liver transplantation. Transplant Proc 21: 3489–3492
17. Kratzer MAA, Dietreich J, Denecke H, Knedel M (1991) Hemostatic variables and blood loss during orthotopic human liver transplantation. Transplant Proc 23: 1906–1911
18. Kuo PC, Affrey EJ, Garcia G, Haddow G, Dafoe DC (1995) Orthotopic liver transplantation with selective use of venovenous bypass. Am J Surg 170: 671–675
19. Kwaan JH, Rappaport I (1970) Postoperative brachial plexus palsy. Arch Surg 101: 612
20. Moreno E, Gomez SR, Gonzalez I, Loinaz C, Garcia I, Perez A, Palomo C, Alvarado A, Maffettone V, Perez-Cerda F (1993) Neurologic complications in liver transplantation. Acta Neurol Scand 87: 25–31
21. Neuhaus P, Platz KP (1994) Liver transplantation: newer surgical approaches. Baillieres Clin Gastroenterol 8: 481–493
22. Oken AC, Frank SM, Merritt WT, Fair J, Klein A, Burdick J, Thompson S, Beattie C (1994) A new percutaneous technique for establishing venous bypass access in orthotopic liver transplantation. J Cardiothorac Vasc Anesth 8: 58–60
23. Ozaki CF, Langnas AN, Bynon JS, Pillen TJ, Kangas J, Vogel JE, Shaw BW Jr (1994) A percutaneous method for venovenous bypass in liver transplantation (comments). Transplantation 57: 472–473
24. Paulsen AW, Whitten CW, Ramsay MAE, Klintmalm GB (1989) Considerations for anesthetic management during veno-venous bypass in adult hepatic transplantation. Anesth Analg 68: 489–496
25. Ramsay MAE, Swygert TH (1992) Anaesthesia for hepatic trauma, hepatic resection and liver transplantation. Baillieres Clin Anaesthesiol. 6: 863–894
26. Rasmussen LS, Ejlersen E, Hjortrup A, Kirkegaard P, Secher NH (1994) Venovenous bypass during human liver transplantation. Transplant Proc 26: 1791
27. Rettke SR, Janossy TA, Chantigian RC, Burritt MF, Van Dyke RA, Harper JV, Ilstrup DM, Taswell HF, Wiesner RH, Krom RAF (1989) Hemodynamic and metabolic changes in hepatic transplantation. Mayo Clin Proc 64: 232
28. Robinson JF, Robinson WA, Cohn A, Garg K, Armstrong JDn (1995) Perforation of the great vessels during central venous line placement (comments). Arch Intern Med 155: 1225–1228
29. Scherer R, Erhard J, Giebler R, Lange R, Schmutzler M, Kox WJ (1994) Percutaneous portofemoro-subclavian venovenous bypass during orthotopic liver transplantation (comment). Transplantation 58: 643–644
30. Scherer R, Giebler R, Erhard J, Lange R, Gunnicker M, Schmutzler M, Paar D, Kox WJ (1994) A new method of veno-venous bypass during human orthotopic liver transplantation. Anaesthesia 49: 398–402
31. Scholz T, Bäckman L, Mathisen Ø, Buø L, Karlsrud T, Johansen HT, Bergan A, Klintmalm GB, Aasen AO (1995) Activation of the plasma contact system and hemodynamic changes after graft revascularization in liver transplantation. Transplantation 60: 36–40
32. Shaw BJ, Martin DJ, Marquez JM, Kang YG, Bugbee AJ, Iwatsuki S, Griffith BP, Hardesty RL, Bahnson HT, Starzl TE (1984) Venous bypass in clinical liver transplantation. Ann Surg 200: 524–534
33. Shaw BW (1987) Some further notes on venous bypass for orthotopic transplantation of the liver. Transplant Proc 19 [Suppl 3]: 13
34. Slooff MJ, Bams JL, Sluiter WJ, Klompmaker IJ, Hesselink EJ, Verwer R (1989) A modified cannulation technique for veno-venous bypass during orthotopic liver transplantation. Transplant Proc 21: 2328–2329
35. Soong WJ, Hwang B (1993) Percutaneous central venous catheterization: five year experiment in a neonatal intensive care unit. Acta Paediatr Sin 34: 356–366
36. Spiekermann BF, Bogdonoff DL, Hershey JE, McLaughlin JD (1995) A method for percutaneous cannulation for veno-veno bypass during orthotopic liver transplantation (letter). Anesth Analg 80: 432–433
37. Starzl TE, Marchioro TL, Von Kaulla KN, Hermann G, Brittain RS, Waddel WR (1963) Homotransplantation of the liver in humans. Surg Gynecol Obstet 117: 659–676
38. Sunder-Plassmann G, Muhm M, Drum W (1996) Placement of central venous catheters by overinsertion of guide wires: low complication rate in 1527 central venous access devices (letter). Nephrol Dial Transplant 11: 911–912
39. Taura P, Beltran J, Garcia-Valdecasas JC, Zavala E, Lacy AM, Balust J, Boada J, Arglada T, Grande L, Visa J (1991) The need for venovenous bypass in orthotopic liver transplantation. Transplantation 52: 730–733
40. Veroli P, el Hage C, Ecoffey C (1992) Does adult liver transplantation without venovenous bypass result in renal failure (comments)? Anesth Analg 75: 489–494