New Model of Veno-venous Bypass for Management of Anhepatic Phase in Experimental Study on Dogs

Z. Chkhaidze, N. Khodeli, O. Pilishvili, D. Partsakhashvili, M. Jangavadze, and D. Kordzaia

ABSTRACT

Blood is shunted from the inferior vena cava and portal vein to the superior vena caval system to prevent congestion in the lower parts of the body during the anhepatic phase (AP) of liver transplantation. It leads to overload in the superior vena caval system retarding cranial outflow due to a nonphysiological blood redistribution. To overcome this problem, we developed a new bypass in dogs: blood is shunted from the inferior (caudal) vena cava and portal vein to the suprahepatic inferior (caudal) vena cava. This model was compared with traditional one with or without a pump. Blood pressure and flow parameters were estimated during 3 hours of AP in four groups of four dogs each. The current study showed that a nontraditional scheme of venous bypass reduced circulatory complications during AP, especially in the cranial vena caval system, although a low rate of congestion remains in the caudal vena cava and portal vein systems. Whereas the same scheme using a pump effectively prevented congestion in all of the systems: cranial, caudal, and portal. We concluded that application of a nontraditional bypass scheme, providing venous blood return into suprahepatic part of caudal vena cava, can be considered to be a method of choice for experimental liver transplantation.

THE clinical outcomes of liver transplantation greatly improved after using veno-venous bypass during the anhepatic phase (AP) which shunted (with a pump or without it) blood from the inferior vena cava and portal vein to the superior vena caval system sought to prevent congestion.[1–4] However, these shunts cause congestion in cranial veins, producing complications whose severity depends on the duration of AP.[5,6] This problem increased in severily after implementation of ex vivo hepatic resection and reimplantation surgery. The same challenge is encountered in experimental settings in which liver transplantation represents important scientific and training models.[2,7] It encouraged us to seek methods (models) of veno-venous bypass that achieved effective and safe prevention of regional blood congestion during AP.[4,8] The aim of the study was to develop a model of veno-venous bypass providing maintenance of hemodynamics in the superior and inferior caval and portal veins systems within physiological norms during an anhepatic phase.

MATERIAL AND METHODS

The experiments were performed on 16 male mongrel dogs weighting 15.0 to 20.0 kg, according to international ethical norms for animal research. Initial anesthesia included droperidol (0.5 mg/kg), dimedrol (1.5 mg/kg), ketolong (2.0 mg/kg) followed by maintenance under artificial ventilation using thiopental sodium (10 mg/kg), relaxants (curamed 0.3 mg/kg), and analgesics (ketolong 2.0 mg/kg).

Animals were randomly divided into four groups (n = 4 each), which differed by the model of veno-venous shunting: traditional scheme group I; infrahepatic segment of caudal vena cava (ISCVC) and portal vein (PV) shunted into the right external jugular vein with pump engagement of venous bypass used in the group I, group II nontraditional ISCVC and PV shunted into suprahepatic segment of caudal vena cava (SSCVC; III); and pump engagement of venous bypass used in group III (group IV; Fig 1).

Duration of AP in all groups was 3 hours. The cannulas of respective sizes (6 Fr, 20 Fr, 24 Fr, and 26 Fr) were inserted and fixed by tourniquet technique in the right external jugular vein (only in groups I and II), PV, ISCVC, and SSCVC (only in groups III and IV). The elements of the hepatoduodenal ligament (PV,

From the Department of Clinical Anatomy and Operative Surgery (Z.C., N.K., O.P., D.P., M.J., D.K.), Faculty of Medicine and the Scientific-Training Center of Experimental Surgery (Z.C., N.K., O.P., D.K.), A. Natishvili Institute of Morphology, I. Javakhishvili State University, Tbilisi, Georgia.

Supported by research budget of the A. Natishvili Institute of Morphology, TSU.

Address reprint requests to Dr. Dimitri Kordzaia, 2 Chiaureli St., Tbilisi 0159, Georgia. E-mail: dimitri.kordzaia@tsu.ge

0041-1345/13/$–see front matter
http://dx.doi.org/10.1016/j.transproceed.2012.10.049

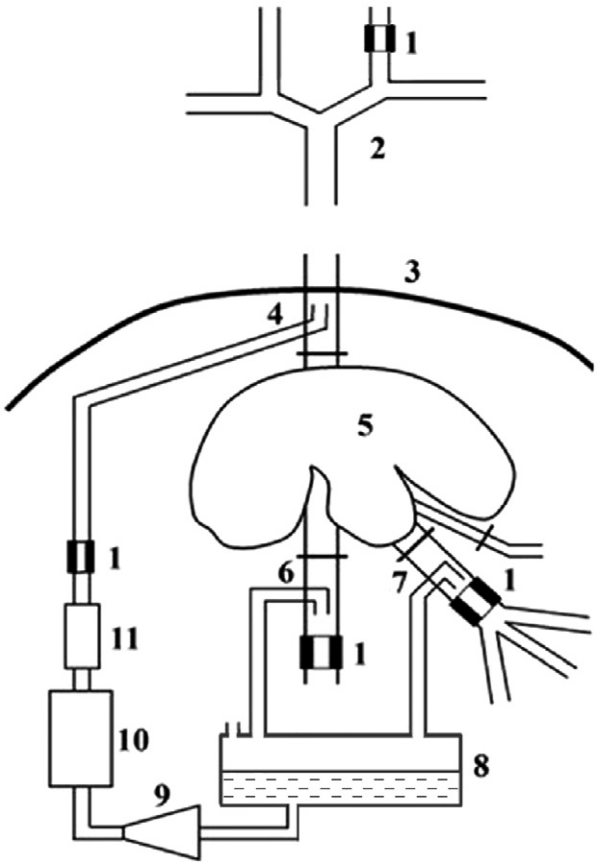

Fig 1. Veno-venous bypass scheme in IV group. (1) Probes for pressure and blood flow; (2) Cranial vena cava system; (3) Diaphragm; (4) Cannula in suprahepatic segment of caudal vena cava; (5) Liver; (6) Cannula in infrahepatic segment of caudal vena cava; (7) Cannula in portal vein; (8) Venous reservoir; (9) Pump; (10) Heat exchanger; (11) Filter.

proper hepatic artery and common bile duct), in the infra- and suprahepatic segments of the caudal vena cava (CVC) were cut maximally close to the liver. The starting point of AP was considered from this moment. In groups II and IV, blood from the ISCVC and PV was collected in an extracorporeal venous reservoir to be returned to the general circulation by pump via a heat exchanger and filter on its way. All surgeries were performed under heparinization (125 IU/kg).

Hemodynamics were monitored by arterial pressure via a direct technique in the left femoral artery. Venous system blood pressure and flow were measured in the PV, ISCVC, left common jugular vein (LCJV), and the tube outgoing from the pump, using a multichannel monitor PM-9000 EXPRESS (Mindray, China-USA) and flowmeter T402-PT (Transonic Systems, USA).

The data registered before the AP was considered to be the baseline. Temperature maintained within initial levels in all groups through the use of a heating pad was monitored by esophageal and anal thermometers. Electrocardiogram and diuresis were controlled during the surgery. Recovered liquid volume was replaced by infusion of 0.9% NaCl. The experimental animals were euthanized by injection of thiopental sodium (25 mg/kg) in the pleural cavity at the end of the experiments.

The significance of differences between the mean values of two groups were calculated using the Student nonpaired *t* test. All statistics were computed with SPSS v15.0 statistical software (SPSS Inc, USA).

RESULTS

Mean pressure in the femoral artery during full AP was maintained within the normal range in all animals (79.1 to 85.8 mm Hg). Blood pressure in the LCJV was increased in groups I and II up to 6.0 ± 1.2 mm Hg and 7.7 ± 1.6 mm Hg, respectively ($P < .05$). In groups III and IV, the changes in initial pressure levels were not significant (Fig 2A). Blood flow in the same vessel in groups I and II was decreased ($P < .05$); in groups III and IV blood flow changes were not significant (Table 1).

Blood pressure in the ISCVC increased in groups I and III to 10.6 ± 2.1 mm Hg and 7.6 ± 1.5 mm Hg, respectively ($P < .05$). In groups II and IV, the changes from initial levels were not significant (Fig 2B). Blood flow in the ISCVC decreased in groups I and III ($P < .05$) but the changes were not significant in groups II and IV (Table 1).

Blood pressure in the PV in group I increased to 12.8 ± 2.2 mm Hg by the end of the third hour of AP ($P < .05$). In groups II and IV, the changes were not significant in these parameters (7.4 ± 1.4 mm Hg and 7.3 ± 0.9 mm Hg, respectively) (Fig 2C). Blood flow in the same vessel significantly decreased in group I during the entire AP and in group III only during the first hour ($p < .05$). Whereas, blood flow changes were not significant in groups II and IV (Table 1).

In groups II and IV, blood pressure and flow in the tube emerging from the pump were managed by the blood volume in the venous reservoir, the blood flow velocity and the cannula diameters.

DISCUSSION

Occlusion of PV and ISCVC for more than 30 minutes during AP leads to severe congestion, hypotension, hypoxic acidosis, hyperkalemia, cardiac arrhythmia, and death in canine liver transplantations.[4,8] Therefore, application of a veno-venous bypass is essential. Furthermore, the traditional scheme of venous bypass, namely, ISCVC and PV shunting into cranial vena cava (CrVC) system, leads to moderate or severe congestion in cranial veins even after only 30 minutes of shunting.[5] Various prevention methods, including new bypass schemes, have been explored to deal with this problem.[1,9]

This study confirmed that traditional shunting schemes without a pump (group I) lead to significant congestion in the CrVC in the CVC, and the PV systems. Although involvement of the pump in the above-mentioned scheme (group II) prevented blood congestion in the CVC and PV systems, it aggravated the problem in cranial veins. Pressure in the LCJV developed during the first hour of AP (from 0.8 ± 0.1 mm Hg to 5.9 ± 0.9 mm Hg; $P < .05$) remaining at high levels to the end of the third hour. The change was