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METHODS OF VENOVENOUS BYPASS DURING LIVER TRANSPLANTATION IN HIGH-RISK SURGICAL PATIENTS (A LITERATURE REVIEW)

D.M. Bondarenko¹, A.R. Monakhov^{1, 2}, S.I. Zubenko¹, M.A. Boldyrev¹

¹ Shumakov National Medical Research Center of Transplantology and Artificial Organs, Moscow, Russian Federation

² Sechenov University, Moscow, Russian Federation

Background. The technique of redirecting blood flow from the inferior vena cava (IVC) and portal vein during liver transplantation (LT) offers several advantages, the most important of which is the prevention of intraoperative hypoperfusion-related complications. **Materials and methods.** A literature search was performed in the Scopus, PubMed, and Russian Science Citation Index (RSCI) databases using the following keywords: “liver bypass”, “liver transplantation with venovenous bypass/shunting”, “assisted circulation during liver surgery”, “assisted circulation during liver transplantation”, and “history of transplantology” from the early 1960s through 2025 were considered. In total, 162 articles from Russian and foreign journals were analyzed, of which 44 met the inclusion criteria and were included in the review. **Results.** An analysis of Russian and foreign literature reveals a unified concept regarding the use of venovenous bypass (VVB) systems, as well as the general advantages and limitations of existing techniques. VVB remains a relevant method for maintaining hemodynamic stability and improving postoperative outcomes in liver transplant recipients. Particular attention is given to a novel system and technique for performing VVB that incorporates an oxygenator/heat exchanger and a venous reservoir, allowing the simultaneous use of continuous renal replacement therapy (CRRT). Modern cardiopulmonary bypass techniques are characterized by the creation of optimal conditions for surgical intervention, ensuring a high level of patient safety throughout the procedure.

Keywords: circulatory support, venovenous bypass, liver transplantation.

Venovenous bypass (VVB) is a cardiopulmonary bypass-based technique used in liver transplantation (LT) to divert blood flow from the inferior vena cava (IVC) and the portal venous system. This approach offers several advantages, most notably reducing the need for complete IVC clamping and thereby minimizing the risk of intraoperative hypoperfusion complications. By maintaining venous return and stabilizing systemic hemodynamics, VVB mitigates complications associated with prolonged clamping of major vessels and improves post-LT outcomes.

Furthermore, VVB shortens the duration of the anhepatic phase, which may decrease the risk of ischemia-reperfusion injury to the graft. It also helps attenuate the severity of post-reperfusion syndrome. Although VVB requires an extracorporeal circuit (ECC) and specialized equipment, its integration into routine LT practice has the potential to improve both early and long-term postoperative outcomes by reducing intraoperative complications related to surgical and anesthetic management [1–3].

The objective of this paper is to analyze the evolution of perfusion technologies and describe current VVB techniques used in LT.

A literature search and study selection were conducted in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines [4]. The identified studies were systematically analyzed, the findings were interpreted, and conclusions were formulated for inclusion in this review. Searches of the Scopus, PubMed, and Russian Science Citation Index (RSCI) databases initially identified 162 publications. Following a two-stage screening process, 44 relevant studies were selected for the final analysis.

The introduction of VVB in LT has a long history marked by significant milestones. The earliest descriptions of VVB techniques were reported by Francis D. Moore in experimental canine studies conducted in the early 1960s. At that time, passive shunting from the left heart to the superior vena cava (SVC) via the internal jugular vein was employed; however, this approach was associated with a high incidence of pulmonary embolism caused by thrombus formation within the ECC [5].

Subsequently, in 1963, Thomas Starzl published a landmark report describing three attempts at human LT, preceded by seven years of research focused on organ preservation, surgical techniques, and the physiologi-

cal relationships between the liver, pancreas, and other abdominal organs. At that stage, the major limitation remained the inadequacy of immunosuppressive therapy. Modifications introduced in 1962 not only improved the management of rejection episodes within the study but ultimately transformed the field of solid-organ transplantation as a whole.

At that time, VVS was performed using separate active venous drainage systems from both the IVC and portal venous circulation, with blood diverted through the femoral and portal veins into the SVC (Fig. 1) [6, 7].

However, according to the authors of these early studies, significant problems arose due to the high incidence of pulmonary embolism, as the ECC itself proved to be a source of thrombus formation. Initial attempts to address this issue through systemic heparinization and venoarterial shunting were subsequently abandoned because of severe, life-threatening complications, particularly uncontrolled bleeding [8].

A major breakthrough occurred in the early 1980s, when a research group from University of Pittsburgh introduced an improved VVS technique using specialized equipment and modified perfusion strategies. The adoption of heparin-coated ECC, the use of centrifugal pumps, and the elimination of systemic heparinization enabled more effective venous perfusion while minimizing the severity of coagulopathy [9, 10].

Subsequent advances further improved bypass technology, including the introduction of Biomedicus centrifugal pumps and the Griffith shunt system. The technique was based on combined active venovenous drainage from the IVC and portal venous systems via the femoral and portal veins, with reinfusion into the SVC through the axillary vein. Over time, open cannulation methods were gradually replaced by percutaneous puncture techniques, significantly reducing complications associated with heparinization and massive intraoperative bleeding during LT.

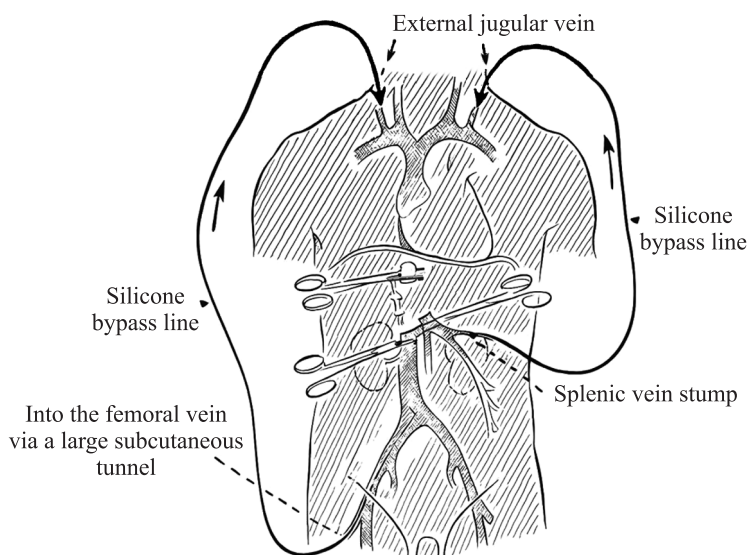


Fig. 1. Schematic representation of blood flow redistribution from the inferior vena cava and portal vein to the superior vena cava system (adapted from Welch C.S. Transplant Bull. 1955 [6])

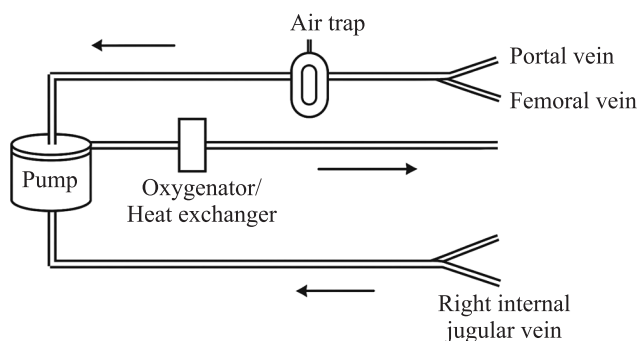


Fig. 2 Schematic representation of veno-venous bypass during liver transplantation (adapted from Butt S.P. et al., The Journal of ExtraCorporeal Technology, 2024 [12])

In addition, the development and implementation of rapid autotransfusion systems – first introduced by the Pittsburgh research group – substantially improved intraoperative blood loss management during LT procedures [10, 11].

According to a study by Butt et al., the perfusion system most commonly used for VVS today consists of a circuit system combined with an oxygenator functioning as a heat exchanger (Fig. 2). This key component extends the conventional configuration, which traditionally includes only a centrifugal pump and perfusion tubing for blood drainage and reinfusion, by enabling precise

temperature regulation for controlled patient warming or cooling during surgery.

In addition, the authors supplement the system with bubble sensors on both the inflow and outflow lines, thereby improving procedural safety by reducing the risk of air embolism. Particular emphasis is placed on the use of heparin-coated materials, which decrease the requirement for systemic anticoagulation and enhance circuit biocompatibility.

The authors also note that a hemoconcentrator may be integrated into the VVS circuit when clinically indicated. However, they do not recommend the routine addition of other auxiliary devices because of the increased risk of air embolism. Instead, when required, continuous renal replacement therapy is performed intraoperatively as a separate procedure [12].

The Austin Health Transplant Center in Melbourne, Australia, analyzed 900 liver transplantations performed between 2008 and 2022 and reported that 27 patients (more than 3%) required emergency intraoperative use of VVS. In an additional 16 cases, the use of VVS had been planned from the outset.

Weinberg et al. reported two VVS configurations: in the first approach, active drainage from either the portal vein or femoral vein was directed into the right internal jugular vein; in the second approach, simultaneous shunting from the femoral and portal veins into the axillary vein was performed without the use of an oxygenator or heat exchanger. This latter technique was comparable to the method originally described by Griffith et al. in 1985 [13].

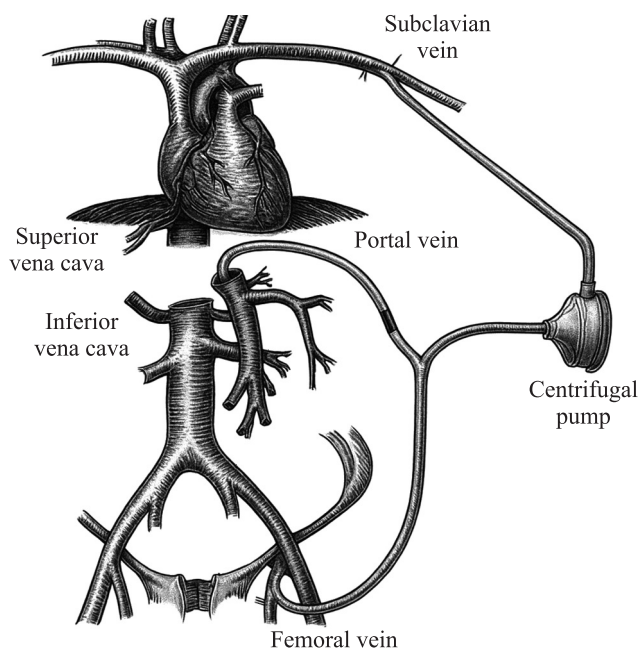


Fig. 3. Venovenous bypass from the portal and femoral veins to the left axillary vein (adapted from Lokshin L.S., Laptiy A.V., Venovenous bypass in orthotopic liver transplantation, 1999 [16])

Despite the availability of the technique and its widespread clinical adoption beginning in the 1980s, the routine use of VVS in LT practice has gradually declined worldwide. Several factors contribute to this trend, including the high cost of VVS, the risks associated with insertion of large-bore catheters and the shunting procedure itself, the potential for hypothermia, and the emergence of alternative techniques [3].

Traditional surgical techniques for LT involve complete cross-clamping and resection of the retrohepatic IVC, together with temporary portal vein clamping. These maneuvers may result in pronounced hemodynamic disturbances, including reduced venous return, decreased cardiac output, distal venous congestion, and organ hypoperfusion, all of which can be life-threatening for patients in poor general health [15].

Analysis of the Russian-language literature revealed relatively limited data on the use of VVS between 1990 and 2012, with 2023 considered separately due to increased research interest. In 1999, Lokshin and Laptiy published a paper titled “Venovenous shunting in orthotopic liver transplantation” in which they reported the use of VVS in 28 patients employing a centrifugal pump with inflow and outflow perfusion lines (Fig. 3). The configuration represented a classical VVS technique. Their study demonstrated the benefits of VVS in preventing ischemic injury to the abdominal organs and kidneys, reducing intraoperative and postoperative complications, and emphasized the necessity of VVS in recipients with certain anatomical features [16, 17].

In 2008, Lutyk published an experimental study titled “Collateral Venovenous Shunting in Liver Transplantation”, which demonstrated the application of a modified VVS system and technique. The study showed that the method provided stable hemodynamic parameters without significant disturbances in patient homeostasis, despite the use of heparin-coated tubing. The authors also emphasized the advantages of centrifugal pumps over roller pumps, as the latter caused mechanical damage to blood cells and resulted in hemolysis in 58% of cases.

The principal modification compared with the classical VVS configuration was the incorporation of a heat exchanger before reinfusion of blood into the axillary vein, thereby enabling maintenance of a controlled temperature throughout the procedure [18, 19, 21].

Following a prolonged period of limited activity in this field, a significant development occurred in 2023, when the Shumakov National Medical Research Center of Transplantology and Artificial Organs registered a patent entitled “System and Method of Extracorporeal Circulation During Liver Surgery”. In addition, Bondarenko et al. reported the use of a proprietary VVS technique incorporating an oxygenator/heat exchanger and a venous reservoir, allowing immediate reinfusion of shed blood into the SVC system via a double-lumen catheter inserted into the jugular vein (Fig. 4) [20].

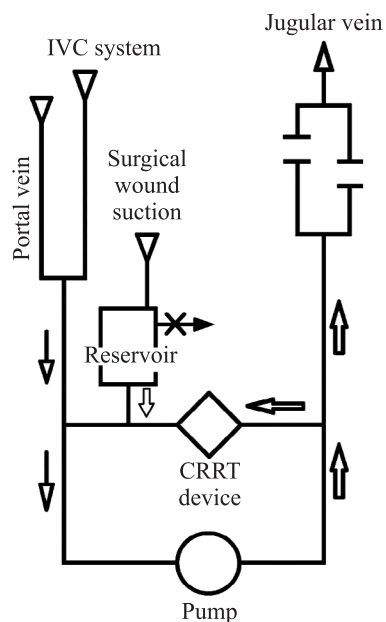


Fig. 4. Schematic representation of veno-venous shunting using an oxygenator/heat exchanger and a venous reservoir [20]. Abbreviations: IVC, inferior vena cava; CRRT, continuous renal replacement therapy

This system and technique combine the advantages of conventional VVS with the ability to control the patient's intravascular volume status, thereby reducing the impact of intraoperative blood loss and decreasing the need for transfusion of blood products during surgery. The percutaneous approach for jugular vein catheterization eliminates many of the disadvantages associated with open surgical access to the axillary vein.

Over the past two decades, VVS techniques have undergone substantial refinement, including the introduction of percutaneous cannulation as a safer and technically simpler alternative to traditional open surgical access. The percutaneous approach has demonstrated advantages in terms of procedural safety and ease of implementation.

Moreover, advances in extracorporeal technologies, including improvements in ECC design, such as integration of heat exchangers to prevent perioperative hypothermia, and the availability of coated (coagulation-inert) circuits for better anticoagulation management, have expanded the clinical applicability and importance of VVS in critically ill patients undergoing LT. Collectively, these innovations have enhanced surgical outcomes [1].

A number of studies evaluating the use of veno-venous/portal (VVP) shunting in LT have reported favorable outcomes. These studies indicate that VVP shunting contributes to intraoperative hemodynamic stability, reduces operative time, and improves postoperative outcomes, particularly in patients with renal dysfunction. Additionally, it has been associated with a lower incidence of complications such as cardiac arrhythmias, pulmonary hypertension, and right ventricular dysfunction. Overall,

these findings support improved recipient safety through a reduction in perioperative surgical risks, thereby reinforcing the role of VVS in minimizing complications and enhancing LT outcomes [2, 3].

In turn, the effectiveness of VVP shunting during LT was further demonstrated by Mossdorf et al., who analyzed 163 consecutive liver transplants performed at a single center following the initiation of its transplant program in 2010. Mean operative time was 269 minutes, while mean warm ischemia time did not exceed 43 minutes. The median requirement for red blood cell and plasma transfusions was 7 and 14 units, respectively. No intraoperative mortality was reported, and the 30-day mortality rate was 3%, with no severe complications attributable to the shunting procedure.

The VVS technique in this series was primarily used to minimize intravascular volume overload, reduce the need for vasopressor therapy, limit myocardial injury, and improve peripheral circulation [14].

In a 2019 comparative study, researchers evaluated the impact of VVS during liver resections involving prolonged vascular isolation and hypothermic organ perfusion. It was found that the use of VVS was associated with significantly reduced intraoperative blood loss ($p = 0.010$) and a lower incidence of postoperative respiratory complications – 15% in the VVS group compared with 64% in patients without VVS ($p = 0.012$).

Although the operative time was longer in the VVS group (460 vs. 375 minutes, $p = 0.023$), no statistically significant differences were observed between the groups in terms of postoperative mortality or incidence of major complications.

These findings highlight the potential benefits of VVS in improving surgical outcomes during complex liver resections involving prolonged vascular isolation and hypothermic liver perfusion. Accordingly, the study supports the recommendation to use this method in such cases [25].

Sakai et al. reported that the introduction of techniques for preserving the retrohepatic segment of the IVC in LT significantly reduced the need for VVS significantly and represented a notable advancement in surgical strategy. Nevertheless, VVS continues to serve as a valuable adjunctive method in LT practice.

Traditionally, venous return cannulation via open access through the axillary vein has been associated with considerable risks, including lymphorrhea, infection, and injury to the brachial plexus. Consequently, in adult LT, percutaneous insertion of the return cannula into the internal jugular vein is now preferred as a safer alternative. This approach not only minimizes procedure-related complications but also improves the overall safety and effectiveness of the surgical intervention [26].

A retrospective study by Sun et al. evaluated the effect of VVS on the development of acute kidney injury (AKI) following LT. Among 1,037 patients included

in the analysis, 247 received intraoperative VVS. The incidence of AKI was significantly lower in patients with pre-transplant renal dysfunction (serum creatinine >1.2 mg/dL) who underwent VVS, and VVS was identified as an independent protective factor against AKI. However, no significant differences were observed in the requirement for renal replacement therapy or 1-year mortality between groups. In patients with normal baseline renal function (creatinine <1.2 mg/dL), the incidence of postoperative hemodynamic disturbances did not differ significantly between VVS and non-VVS groups. Overall, the findings suggest that intraoperative VVS may reduce the risk of post-transplant renal complications in patients with pre-existing renal impairment, although further studies are required to confirm this effect [27].

In another report, Rocco et al. described two cases of complex orthotopic LT in which VVS was employed to manage the porto-mesenteric compartment, with venous grafts anastomosed either to the inferior mesenteric vein (IMV) or the splenic vein (SV). In both cases, a percutaneous femoral-axillary VVS was established prior to abdominal incision to facilitate control of massive collateral circulation within the abdominal wall. In the first case, the IMV was anastomosed to a donor venous graft, while in the second case, severe splenomegaly necessitated splenectomy, after which the SV was similarly anastomosed to the donor venous graft.

In both cases, connecting the distal end of the venous graft to the VVS circuit enabled effective decompression of the porto-mesenteric compartment. This resulted in a reduction in portal hypertension and improved surgical access to the hepatic hilum, which was particularly important in the context of complex dissection following previous extensive surgeries. The described technique is considered both safe and technically straightforward, and it may serve as a valuable alternative in patients requiring VVS who lack standard portal venous access, particularly in cases of severe portal hypertension or repeat LT procedures [12].

An unusual clinical case reported by Salloum et al. described a previously undocumented approach to VVS during LT using a patent paraumbilical vein. In this patient, preoperative computed tomography revealed a significantly dilated paraumbilical vein. Prior to abdominal incision, a percutaneous femoro-axillary VVS was established and subsequently connected to the paraumbilical vein, enabling continuous splanchnic venous decompression throughout the entire surgical procedure.

The successful use of the paraumbilical vein for VVS in this case suggests a promising approach for similar clinical scenarios in the future [28].

In 2024, Butt et al. from Abu Dhabi (United Arab Emirates) reported their experience with VVS in LT in a cohort of 11 patients with varied indications, including high Model for End-Stage Liver Disease (MELD) scores, prior abdominal surgeries with adhesions, recur-

rent spontaneous bacterial peritonitis, portal vein thrombosis, and coronary artery disease with heart failure. The authors reported favorable outcomes, with no vascular complications related to cannulation and no technical issues associated with the VVS circuit. Notably, post-reperfusion syndrome was not observed in any of the cases [12].

The potential benefits of VVS include improved hemodynamic stability during the anhepatic phase due to preservation of venous return, reduced intraoperative blood loss in the setting of portal hypertension, and maintenance of perfusion to vital organs [10, 29]. In addition, patients with metabolic or cholestatic liver diseases – even in the absence of clinically significant portal hypertension – may still be at risk of portal congestion and therefore benefit from VVS or temporary portocaval shunting.

VVS may also facilitate blood flow redirection in cases of complex vascular anatomy or technically demanding surgery, such as massive hepatomegaly, while enabling decompression of the porto-mesenteric circulation [3] and reducing diffuse abdominal bleeding from venous collaterals [14]. Finally, in cases of fulminant liver failure, VVS may help maintain venous return and reduce excessive fluid administration, thereby potentially limiting worsening intracranial hypertension and potential cerebral edema.

However, several authors have reported that in most comparative studies of LT outcomes with and without routine use of VVS, no statistically significant differences were observed in operative time [9–13], blood product transfusion requirements [22, 23, 30], early postoperative mortality [31], incidence of postoperative AKI [24, 32], early postoperative complication rates [24, 33], or length of hospital stay [23, 32, 34]. Based on these findings, some investigators do not recommend routine use of VVS, although they acknowledge that it may still be justified in selected clinical situations where specific indications are present [13].

In line with current clinical trends, the decision to employ VVS should therefore be made on an individual, case-by-case basis, taking into account clearly defined indications and contraindications. Liver surgery in high-risk patients may be associated with substantial acute blood loss, necessitating immediate restoration of circulating blood volume. The use of blood reinfusion systems (CellSaver) does not always provide immediate reinfusion, this process requires a certain amount of time [35, 36].

Thus, while ongoing improvements in VVS systems have enhanced the safety and feasibility of the technique, the resolution of existing challenges has also given rise to new issues that require further investigation. Current practices among Russian scientists, as well as global trends, indicate that LT is increasingly performed without routine use of VVS.

This global transition toward selective, rather than routine, application of VVS – based on specific disease indications, patient condition, and expanded surgical criteria – reflects growing interest in assisted circulation during LT. It also highlights efforts to address current controversies and unresolved issues, with the overarching goal of improving procedural safety.

The authors declare no conflict of interest.

REFERENCES

1. *Lapisatepun W, Lapisatepun W, Agopian V, Xia VW.* Venovenous Bypass During Liver Transplantation: A New Look at an Old Technique. *Transplant Proc.* 2020 Apr; 52 (3): 905–909. doi: 10.1016/j.transproceed.2020.01.048.
2. *Reddy K, Mallett S, Peachey T.* Venovenous bypass in orthotopic liver transplantation: time for a rethink? *Liver Transpl.* 2005 Jul; 11 (7): 741–749. doi: 10.1002/lt.20482.
3. *Fonouni H, Mehrabi A, Soleimani M, Müller SA, Büchler MW, Schmidt J.* The need for venovenous bypass in liver transplantation. *HPB (Oxford).* 2008; 10 (3): 196–203. doi: 10.1080/13651820801953031.
4. *Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD et al.* The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ.* 2021; 372: n71. doi: 10.1136/bmj.n71.
5. *Moore FD, Wheele HB, Demissianos HV, Smith LL, Balankura O, Abel K et al.* Experimental whole-organ transplantation of the liver and of the spleen. *Ann Surg.* 1960 Sep; 152 (3): 374–387.
6. *Welch CS.* A note on transplantation of the whole liver in dogs. *Transplant Bull.* 1955; 2: 54–55.
7. *Starzl TE, Marchioro TL, Waddell WR.* The reversal of rejection in human renal homografts with subsequent development of homograft tolerance. *Surg Gynecol Obstet.* 1963 Oct; 117: 385–395.
8. *Starzl TE, Iwatsuki S, Van Thiel DH, Gartner JC, Zitelli BJ, Malatack JJ et al.* Evolution of liver transplantation. *Hepatology.* 1982 Sep-Oct; 2 (5): 614–636. doi: 10.1002/hep.1840020516.
9. *Shaw BW Jr, Martin DJ, Marquez JM, Kang YG, Bugbee AC Jr, Iwatsuki S et al.* Venous bypass in clinical liver transplantation. *Ann Surg.* 1984 Oct; 200 (4): 524–534. doi: 10.1097/00000658-198410000-00013.
10. *Griffith BP, Shaw BW Jr, Hardesty RL, Iwatsuki S, Bahnson HT, Starzl TE.* Veno-venous bypass without systemic anticoagulation for transplantation of the human liver. *Surg Gynecol Obstet.* 1985 Mar; 160 (3): 270–272.
11. *Myers GJ.* Perfusion applications during liver transplantation. *Perfusion.* 1987 Jan; 2 (1): 51–56.
12. *Butt SP, Kumar A, Ashiq F, Minou A, Iuppa G, Quintini C.* Venovenous bypass in liver transplantation: Exploring the benefits, efficacy, and safety. *J Extra Corpor Technol.* 2024 Jun; 56 (2): 77–81. doi: 10.1051/ject/2024005.
13. *Weinberg L, Caragata R, Hazard R, Ludski J, Lee DK, Sliwinski H et al.* Venovenous bypass in adult liver transplant recipients: A single-center observational case series. *PLoS One.* 2024 May 31; 19 (5): e0303631. doi: 10.1371/journal.pone.0303631.
14. *Mossdorf A, Ulmer F, Junge K, Heidenhain C, Hein M, Temizel I.* Bypass during Liver Transplantation: Anachronism or Revival? Liver Transplantation Using a Combined Venovenous/Portal Venous Bypass-Experiences with 163 Liver Transplants in a Newly Established Liver Transplantation Program. *Gastroenterol Res Pract.* 2015; 2015: 967951. doi: 10.1155/2015/967951.
15. *Estrin JA, Belani KG, Ascher NL, Lura D, Payne W, Najarian JS.* Hemodynamic changes on clamping and unclamping of major vessels during liver transplantation. *Transplant Proc.* 1989 Jun; 21 (3): 3500–3505.
16. *Lokshin LS, Laptiy AV.* Veno-venous bypass in orthotopic liver transplantation. *Pathology of blood circulation and cardiac surgery.* 1999; (1): 49–53.
17. *Laptiy AV.* Veno-venous bypass in orthotopic transplantation and extensive liver resections: Experimental and clinical study: Abstract of a PhD thesis. Moscow, 1999; 23.
18. *Zhuravel SV, Chugunov AO, Lutsyk KN, Timerbayev VKh, Chzhao AV.* Advantages and Disadvantages of Vein-Venous Bypass During Liver Transplantation. *General resuscitation.* 2008; 4 (5): 70–74.
19. *Lutsyk KN, Chugunov AO, Zhuravel SV, Novruzbekov MS, Zhao AV.* Features of venovenous bypass surgery in liver transplantation. *Annals of surgical hepatology.* 2005; 10 (2): 205b–205.
20. *Bondarenko DM, Sdvigova AG, Zubenko SI, Monakhov AR, Ustin SY, Poptsov VN.* System and method for circulatory support during liver surgery. Patent holder: V.I. Shumakov National Medical Research Center of Transplantology and Orthopedics, Ministry of Health of the Russian Federation. – 2023. – No. 2812592.
21. *Lutsyk KN.* Bypass venovenous shunting in liver transplantation: Abstract of Cand. Sci. (Medicine) Dissertation. Moscow, 2008; 19.
22. *Kuo PC, Alfrey EJ, Garcia G, Haddow G, Daffoe DC.* Orthotopic liver transplantation with selective use of venovenous bypass. *Am J Surg.* 1995 Dec; 170 (6): 671–675. doi: 10.1016/s0002-9610(99)80039-7.
23. *Sakai T, Matsusaki T, Marsh JW, Hilmi IA, Planinsic RM.* Comparison of surgical methods in liver transplantation: retrohepatic caval resection with venovenous bypass (VVB) versus piggyback (PB) with VVB versus PB without VVB. *Transpl Int.* 2010 Dec; 23 (12): 1247–1258. doi: 10.1111/j.1432-2277.2010.01144.x.
24. *Schmitz V, Schoening W, Jelkmann I, Globke B, Pascher A, Bahra M et al.* Different cava reconstruction techniques in liver transplantation: piggyback versus cava resection. *Hepatobiliary Pancreat Dis Int.* 2014 Jun; 13 (3): 242–249. doi: 10.1016/s1499-3872(14)60250-2.
25. *Navez J, Cauchy F, Dokmak S, Goumard C, Faivre E, Weiss E.* Complex liver resection under hepatic vascular exclusion and hypothermic perfusion with versus without veno-venous bypass: a comparative study. *HPB (Oxford).* 2019 Sep; 21 (9): 1131–1138. doi: 10.1016/j.hpb.2018.12.012.
26. *Sakai T, Gligor S, Diulus J, McAfee R, Wallis Marsh J, Planinsic RM.* Insertion and management of percutaneous veno-venous bypass cannula for liver trans-

- plantation: a reference for transplant anesthesiologists. *Clin Transplant*. 2010 Sep-Oct; 24 (5): 585–591. doi: 10.1111/j.1399-0012.2009.01145.x.
27. Sun K, Hong F, Wang Y, Agopian VG, Yan M, Busuttil RW. Venovenous Bypass Is Associated With a Lower Incidence of Acute Kidney Injury After Liver Transplantation in Patients With Compromised Pretransplant Renal Function. *Anesth Analg*. 2017 Nov; 125 (5): 1463–1470. doi: 10.1213/ANE.0000000000002311.
 28. Salloum C, Lim C, Lahat E, Compagnon P, Azoulay D. The veno-venous bypass in liver transplantation: an unfinished product. *Hepatobiliary Surg Nutr*. 2016 Jun; 5 (3): 269–272. doi: 10.21037/hbsn.2016.02.03.
 29. Shaw BW Jr, Martin DJ, Marquez JM, Kang YG, Bugbee AC Jr, Iwatsuki S. Advantages of venous bypass during orthotopic transplantation of the liver. *Semin Liver Dis*. 1985 Nov; 5 (4): 344–348. doi: 10.1055/s-2008-1040631.
 30. Hesse UJ, Berrevoet F, Troisi R, Mortier E, Pattyn P, de Hemptinne B. Liver transplantation by preservation of the caval flow with temporary porto-caval shunt or veno-venous bypass. *Transplant Proc*. 1997 Dec; 29 (8): 3609–3610. doi: 10.1016/s0041-1345(97)01044-0.
 31. Lerut JP, Molle G, Donatiggio M, De Kock M, Ciccarelli O, Laterre PF et al. Cavocaval liver transplantation without venovenous bypass and without temporary portocaval shunting: the ideal technique for adult liver grafting? *Transpl Int*. 1997; 10 (3): 171–179. doi: 10.1007/s001470050037.
 32. Cabezuolo JB, Ramirez P, Acosta F, Torres D, Sansano T, Pons JA. Does the standard vs piggyback surgical technique affect the development of early acute renal failure after orthotopic liver transplantation? *Transplant Proc*. 2003 Aug; 35 (5): 1913–1914. doi: 10.1016/s0041-1345(03)00598-0.
 33. Moreno-Gonzalez E, Meneu-Diaz JG, Fundora Y, Ortega P, Moreno Elola-Olaso A, García García I. Advantages of the piggy back technique on intraoperative transfusion, fluid compsumption, and vasoactive drugs requirements in liver transplantation: a comparative study. *Transplant Proc*. 2003 Aug; 35 (5): 1918–1919. doi: 10.1016/s0041-1345(03)00600-6.
 34. Reddy KS, Johnston TD, Putnam LA, Isley M, Ranjan D. Piggyback technique and selective use of venovenous bypass in adult orthotopic liver transplantation. *Clin Transplant*. 2000 Aug; 14 (4 Pt 2): 370–374. doi: 10.1034/j.1399-0012.2000.14040202.x.
 35. Li C, Mi K, Wen TF, Yan LN, Li B, Wei YG. Risk factors and outcomes of massive red blood cell transfusion following living donor liver transplantation. *J Dig Dis*. 2012 Mar; 13 (3): 161–167. doi: 10.1111/j.1751-2980.2011.00570.x.
 36. Donohue CI, Mallett SV. Reducing transfusion requirements in liver transplantation. *World J Transplant*. 2015 Dec 24; 5 (4): 165–182. doi: 10.5500/wjt.v5.i4.165.

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