Features of the Restoration of Arterial Circulation in Liver Transplantation

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Abstract

Objectives. Violations of tissue blood supply remain one of the most serious complications after liver transplantation.

Design. To improve the surgical technique of performing reconstructive interventions on the arteries of the donor and the recipient in order to reduce the frequency of its thrombosis after liver transplantation.

We studied 25 donors, 20 men and 5 women, the mean age was 56± 4 years, eighteen of them had left aberrant supplementary artery, which in fifteen departed from the left gastric artery and in three from the aorta above the ventricular stem. Seventeen had the right aberrant artery moving away from the upper mesenteric artery. Twenty recipients with liver cirrhosis (eleven with primary biliary cirrhosis, five with primary sclerosing cholangitis, five with viral etiology C cirrhosis, and three of the lower cirrhosis-cirrhosis disseminated within the Milan criteria. All recipients had standard anatomical branching of the arteries of the liver. The average age was 50±6.

All recipients had standard anatomical branching of the liver arteries. Patients underwent liver transplantation with new methods of reconstructive interventions on the donor and recipient arteries.

The developed technique provides the shortest pathway of the recipient's arterial blood to the liver transplant, through the superior mesenteric artery provides an alternative source of arterial blood supply from the aorta in which this transplant additionally needs.

Presented method of blood circulation restoration at liver transplantation at abnormal structure of arterial channel of the liver transplant is performed inside the recipient's abdominal cavity. At first, blood flow is restored along the reconstructed common hepatic artery, after the right or left aberrant arteries liver transplant. Such technique provides the shortest route of the recipient's arterial blood to the liver transplant, through the upper mesenteric artery provides an alternative source of arterial blood supply from the aorta for which the transplant is additionally needed. This new method of blood circulation restoration provides an opportunity to avoid the formation of "kinking" syndrome, in the occurrence of which the blood vessels are lengthened, the angulation and location of the blood vessel in relation to the grafts and other abdominal organs. This reduces the risk of thrombosis of the arteries of the transplanted liver.

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Introduction

Violations of tissue blood supply remain one of the most severe complications after liver transplantation and are often associated with irreversible ischemic damage of the transplanted organ, causing massive necrosis of hepatocytes,

biliary epithelium, which serves as a trigger mechanism for polyorganic failure and sepsis[1]. The only hope for saving the life of a patient in such a situation is urgent retransplantation, which is limited both by an acute deficit of donor organs and by the extremely severe condition of the recipient himself[2]. Therefore, the prevention of vascular complications, the use of optimal methods of vascular reconstructive interventions is of paramount importance to improve early and distant liver transplantation results. Arterial thrombosis after liver transplantation is 64-82% of all postoperative vascular complications[3].

According to the literature, the frequency of arterial thrombosis was 12% in adult recipients and 42% in children - to date there has been a significant improvement in the results of operations, arterial thrombosis is 4.4%, and in children about 8.3%[1]. Therefore, arterial complications after liver transplantation remain the most discussed, and the existing discussions remain ambiguous, and sometimes contradictory, judgments and views on this issue[4].

In spite of surgical factors that remain dominant in the genesis of liver artery thrombosis, it has been established that the cause of arterial complications after organ transplantation remains multifactorial and depends not only on arterial anastomosis formation[5,6]. The technical causes of hepatic artery thrombosis include tactical and technical errors made at the donor stage of the operation. Excessive secretion of the donor's liver artery, breakage of intima, damage of its wall, formation of perivascular hematomas contribute to hepatic artery thrombosis[1].

One of the prerequisites for arterial thrombosis development is variant arterial anatomy of the donor liver, and according to different sources, the number of vascular abnormal branches is up to 40% of the total number[7,8]. During removal of a donor organ, errors in determining the arterial channel of the liver can lead to damage of the artery of the graft[8,9]. But the presence of several sources of arterial blood supply to the liver requires complex arterial interventions, which is also one of the risk factors for arterial thrombosis [1,6,8,9]. This is confirmed by other researchers who show that variant arterial branching and additional performance of reconstructive interventions are accompanied by a higher percentage of thrombosis in comparison with operations performed at standard anatomy[10,11]. Other researchers do not consider either variant anatomy or arterial reconstructions to be risk factors for hepatic artery thrombosis[8,12]. Thus, there is no consensus on the influence of non-standard arterial anatomy on liver transplant arterial thrombosis, and discussions on this issue persist[13].

The purpose of the study. To improve the surgical technique of performing reconstructive interventions on the arteries of the donor and recipient in order to reduce the frequency of her thrombosis after liver transplantation.

Materials and methods

We studied 25 donors, 20 men and 5 women, the mean age was 56± 4 years, eighteen of them had left aberrant supplementary artery, which in fifteen departed from the left gastric artery and in three from the aorta above the ventricular stem (Fig. 1).

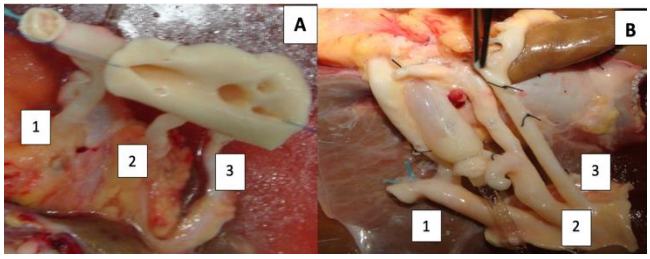

Figure 1. Three sources of arterial blood flow to the liver.

Mouth view (A) and side view (B) 1- Additional right hepatic artery diverges from the upper mesenteric artery, 2- Left additional hepatic artery diverges from the aorta, 3- and right and left hepatic arteries diverge from the aorta and the ventricular trunk.

The ethics of research and clinical practice are regulated by the national standard of the Russian Federation GOST R 52379-2005 "Good Clinical Practice", approved by Order of the Federal Agency for Technical Regulation and Metrology of September 27, 2005 No. 232-st.

Seventeen had the right aberrant artery moving away from the upper mesenteric artery. (Figure 1). Twenty recipients with liver cirrhosis (eleven with primary biliary cirrhosis, five with primary sclerosing cholangitis, five with viral etiology C cirrhosis, and three of the lower cirrhosis-cirrhosis disseminated within the Milan

criteria. All recipients had standard anatomical branching of the arteries of the liver. The average age was 50±6.

In total, twenty-five new surgical interventions were performed: ten with right and fifteen with left aberrant arteries of the donor's liver. Comparison with a control group of twenty-five patients who had previously been operated on using the traditional method showed that the time of liver implantation had not increased. Ischemic and reperfusion injuries in the early postoperative period were 15% less than in the group operated with the traditional method and amounted to ≤ 600 IU. All surgeries with the new surgical technique were performed without complications, there were 3 complications in the control group related to hemodynamic disorders. The average hospitalization time using the new surgical technique was 15 days, in contrast to 21 days in the control group.

Liver transplantation was performed by the new methods of reconstructive interventions on the arteries of the donor and recipient described below.

We performed twenty-five reconstructive interventions inside the recipient's abdominal cavity. The gastro-duodenal artery of the recipient was cut off from the common hepatic artery and preserved. Carrel's sites were prepared from the stumps of the recipient's and donor's common hepatic and gastroduodenal arteries (shown in Fig. 2(2) 4a, b,5(1), which was immediately anastomosed with a similar site made of the donor's common hepatic and gastroduodenal arteries (Fig. 2(1), 4 c, d).

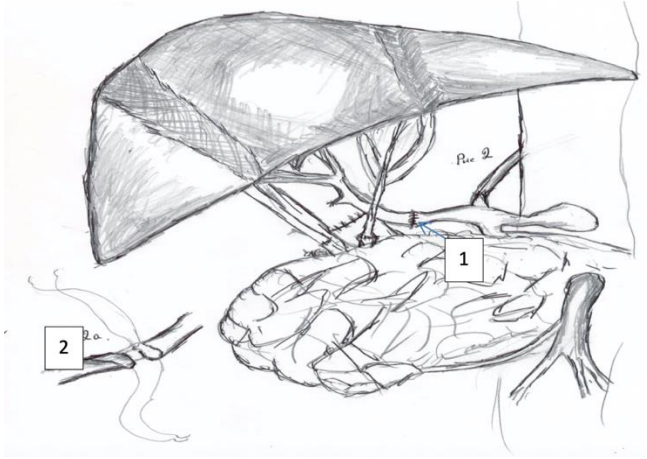

Figure 2. (1,2) a) Vascular anastomosis between the stump of the recipient's gastroduodenal artery and the left aberrant artery was performed.

Figure 3(a,b,c,) 4(1) shows the stages of performing such operations. It is quite convenient to perform anastomosis between Carrel's sites and the common hepatic artery and gastroduodenal artery of the recipient and donor (Fig. 3 a,b,c). This artificially increases the size of the cross-linked wall fragments. The sites increase the ability to expand anastomosis and increase its strength. When the lower nodal stitch is pulled upwards and to the right, and the upper nodal stitch to the left, the angle of operation improves, the line of the right anastomosis wall is uniformly formed, after sewing with the wavy stitch. Then, with the help of the threads that served as holders, the anastomosis was simultaneously turned in the other direction and the anastomosis line of the left wall was formed.

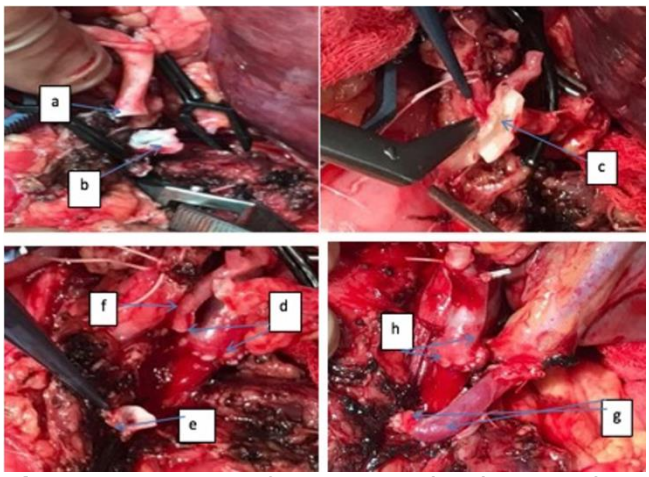

Figure 3. Stages of reconstructive interventions used in the left aberrant artery.
a - the cult of the common hepatic artery of the donor;
b - the stump of the common hepatic artery of the recipient;
c - the lower wall of the anastomosis is formed between the sites of the ventricular-duodenal artery of the donor and recipient;
d - performed anastomosis between the hepatic artery of the donor and the recipient;
e - dissected the stump of the gastroduadenal artery of the recipient;
f- The cut-off end of the left aberrant artery of a liver transplant;
g - made anastomosis between the left aberrant artery and the gastro-duodenal artery;
h - anastomosis is made between the common artery of the recipient and the common artery of the liver transplant using gastroduadenal rinsing of the donor and the recipient.

Before suturing the left wall, we performed a revision of the already performed internal side of the anastomosis for uncontrolled sewing of the opposite wall, and after finishing the anastomosis (Fig. 3c, d, 5a, b) of the cross-linked vessels. Comparable sites provided the optimal angle of the operative activity and (angulation) blood flow

from the recipient to the liver transplant (Fig. 3 d.6 a,b.).

As the division of the common hepatic artery into the right and left arteries is most often located higher - in ligament tissue, the formation of an excess of the reconstructed vascular channel ("kinking syndrome") or twisting along the axis relative to each other is excluded, and the performed anastomosis is less prone to thrombosis.

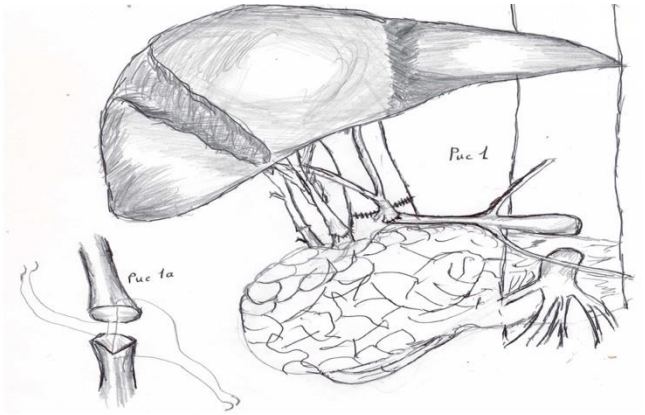

Figure 4. (1, 2) Vascular anastomosis between the stump of the recipient's gastric duodenum artery and the right aberrant artery was performed.

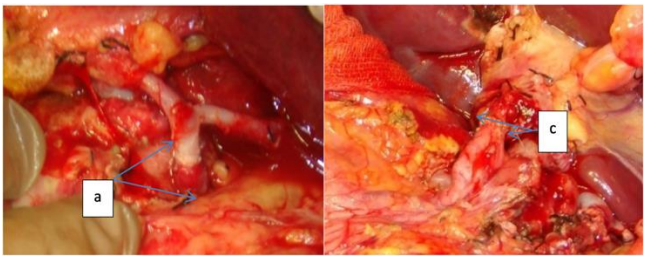

Figure 5. (a, b) presents a wide anastomosis formed from two Carrell sites formed from the gastric duodenum artery and the common hepatic artery, donor, and recipient.

This method has fully justified itself in the normal branching of the arterial channel of the donor liver (Figures 5a, b).

The second stage was an additional restoration of blood circulation in the aberrant arteries. Anastomosis between the aberrant right or left hepatic arteries of the donor's liver and the recipient's gastroduodenal artery was performed. Before performing vascular anastomosis, the end of the gastroduodenal artery was cut for two of its diameters, the left aberrant artery was cut off just below the branch to the small curvature of the stomach, which allowed to get from the bifurcation formed at the end of the site Carrel, which was sewn into the prepared stump of the gastric duodenal artery (Fig. 2, 4 d.). To ensure an optimal angle when restoring the right aberrant artery of the gastro-duodenal artery, it was isolated from the connective tissue near the head of the pancreas, which was then dissected, as in the first case, and the right aberrant artery was dissected on the opposite side. After performing two nodal sutures on the angular sections, the ends of the threads were pulled up, the resulting line between the two sections of the vessels in the form of "rhombus" sutures were sutured with wrapped sutures. Such anastomoses provided the shortest arterial blood path from the recipient to the liver transplant and the necessary angulation, and the location of the proximal fragment of the right aberrant artery in the liver duodenal ligament tissues also excludes its rotation along the pulse wave axis (Figs. 2, 3, 4).

The proposed method allowed to perform a sufficiently strong anastomosis and not to narrow it down even at diameter ≤ 4 mm, and additionally - from another source (upper mesenteric artery) to increase the blood volume for the transplanted organ.

Results

For normal function of the transplanted organ with variable arterial channel, complete restoration of blood circulation during liver transplantation is of paramount importance.

For this purpose, extracorporeally or on the "back-table" stage, the cult of splenic, upper-mesenteric or gastro- duodenal artery of the donor was most often used, in which aberrant arteries were sutured, providing a single arterial channel (Fig. 6 a, b, d.). Using the stump of the gastric duodenum artery of the donor's liver, the anatomical features allowed to obtain a construction with the right aberrant artery of optimal length and angulation (Fig. 6b), but after the start of blood flow increases the length, changes and angulation.

If we take into account that the recipient's arterial channel is also variable, then it is quite difficult to calculate the necessary length of the reconstructed section after the pulsating wave, anastomosis departure angle, rotation of the reconstructed section extracorporeally. If the

donor's liver before the implantation had two or even three sources of arterial blood supply (ventricular stem, upper mesenteric artery and aorta), then the combined blood flow into one channel (more often through the ventricular stem) will not provide the organ with the necessary amount of arterial blood, because the regulatory function of the sympathetic and parasympathetic nervous system in the transplant is absent. Therefore, the completeness of the performed reconstruction raises some doubts, because the aberrant arteries included in a single channel take a part of the blood, "stealing" the main channel of the common hepatic artery.

Thus, at abnormal branching of the arteries of the liver it is not always possible to create an adequate vascular channel (Fig. 6 a,b,d.). The method does not provide the shortest route of arterial blood from the recipient to the donor liver and optimal angulation; more often, when the blood flow is started, excess blood vessels are obtained, which lengthen the arterial channel, changes the angulation of the reconstructed section, and excessive rotation increases vascular resistance, reduces the speed of blood flow and promotes thrombosis of the reconstructed artery. In addition, the aberrant arteries included in a single channel take part of the arterial blood, stealing the main channel of the common hepatic artery.

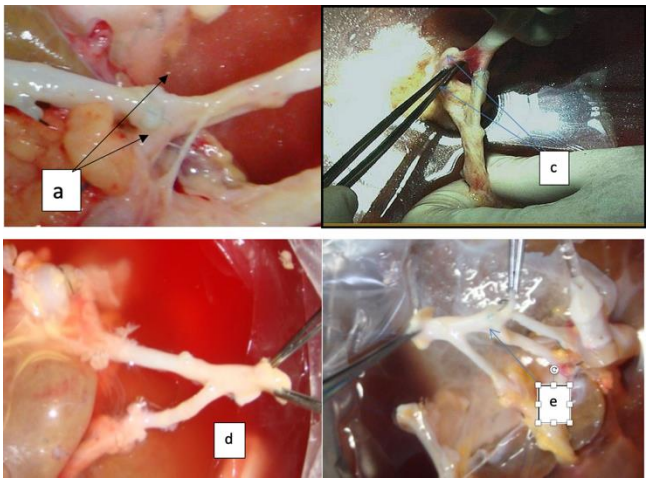

Figure 6. Extracorporeal arterial reconstruction: (a) right abbent hepatic artery anastomized with the mouth of the gastroduodenal artery (b) left abbent hepatic artery anastomized with the mouth of the gastroduodenal artery. (c) The right and left hepatic artery is divided in the region of the hepatic artery and blood is supplied to the right and left lobes of the liver and passes through the hepatic duodenal ligament and the small gland. d) The left extra hepatic artery retreats from the left gastric artery, the left hepatic artery from the ventricular trunk and the right hepatic artery retreats from the upper mesenteric artery and is anastomized with a stump of the splenic artery.

Carrel's sites were prepared from the stumps of the recipient's and donor's common hepatic and gastroduodenal arteries (shown in Fig.2(2) 4a, b,5(1), which was immediately anastomosed with a similar site made of the donor's common hepatic and gastroduodenal arteries (Fig.2(1), 4 c,d).

We consider that in case of abnormal branching of the arterial channel it is most preferable to perform reconstructive interventions in the recipient's abdominal cavity. Only there, directly at the recipient can be calculated and adequate length of the restored arterial channel, the departure angle of the created anastomosis, and the location of the vessels even after the pulse wave provides minimization of rotation and the shortest path of arterial blood from the recipient to the liver, and avoid stenosis of the performed anastomoses. All this together reduces the possibility vascular thrombosis and post-op death.

Clinical Case 1. Patient C, 54, was admitted to the clinic with the diagnosis of primary sclerosing cholangitis, cirrhosis of the liver, portal hypertension with repeated bleeding from the esophageal varices. Received a single-group donor liver from a donor 52 years after finding brain death, which had an aberrant right hepatic artery extending from the upper mesenteric artery with a significant excess. Hepatectomy was performed under anesthesia, preserving the retrohepatic region of the inferior vena cava. After the implantation, with the use of cava-caval anastomosis, restoration of the portal vein and blood flow along it, the reconstructive intervention on the arterial channel was performed using the technique already presented above. Initially, the common hepatic artery was reconstructed with the help of Carrel sites made of the stump of the common hepatic artery and the gastroduodenal artery of the recipient and donor. Then the preserved section of the gastroduodenal artery was isolated from the connective tissue for 1.5 cm, which allowed to obtain an adequate angle

for anastomosis with the right aberrant liver artery. The end sections of the recipient's gastro-duodenal artery and the right aberrant artery were dissected in front of each other to provide sites for a wide anastomosis; the upper wall of the recipient's gastro-duodenal artery and the lower wall of the right aberrant artery were connected by a continuous winding vascular suture. Artificially created sites on the end fragments of the vessels provided expansion of the anastomosis by the type of "rhombus" and convenience of its execution. The biliary duct was reconstructed according to the type of biliodigestive anastomosis with small intestine on a loop along the Ru "end to side". The patient was discharged home after two weeks in satisfactory condition.

Clinical Case 2. Patient K. Entered the department for 60 years with the diagnosis of cirrhosis of the liver With viral etiology, with portal vein thrombosis, portal hypertension, ascites. The resulting liver from a 53-year-old donor had a left aberrant artery departing from its left gastric artery, a branch of the ventricular trunk at the beginning of its formation with a significant excess in length. Hepatectomy and liver transplantation with "piggy beak" technology were performed under intubation anesthesia. After successful thrombintimectomy from the recipient's portal vein and the obtained good blood flow, kava-kaval anastomosis was performed and the blood flow along the transplant's portal vein was restored. Restoration of arterial channel of the transplanted organ was performed as follows. The recipient's liver arteries were isolated before the gastro-duodenal artery, which was crossed, the distal stump was clenched with a vascular clamp of de Becky type, and from the proximal stump of the gastro- duodenal and common hepatic arteries the Carrel's site was formed, which was anastomosed with the similar site of the common hepatic, gastroduodenal artery of the donor graft.

The preserved distal stump of the gastroduodenal artery was dissected along the upper wall by 2 its diameter, and the distal end of the left aberrant liver artery was dissected to the required length. The cult of the donor aberrant artery was formed at the level of the departure of one of the large branches, which blood supply a small curvature of the donor's stomach - which was dissected along the shooting gallery of the Carrel site. This preliminary preparation provided a stronger, broader anastomosis and made it easier to perform the vascular suture taking into account the necessary rotation and angulation. In the end, the biliary tract was reconstructed with biliary anastomosis end to end with a wrapped vascular suture. The ultrasound scan and duplex scan after the operation showed effective blood flow on both vessels. The postoperative period proceeded without complications, the patient was discharged from the ward for 12 days.

The six-month period of observation showed the permeability of both restored arteries and normal function of the transplanted organs in the group of new surgical interventions; in the control group there were 3 above-mentioned complications.

Discussion

There are extracorporeal methods of reconstructive interventions on the arteries before the donor organ implantation, when from one, two or even three arteries, which supply blood to the liver, coming from the left gastric, upper mesenteric artery or even from the aorta, uniting them together outside the abdominal cavity, one channel is obtained[8, 14, 15]. The main task of arterial interventions at the "back-table" stage was to reduce ischemic injuries by accelerating the process of arterial blood flow to the recipient's liver transplant.

For this purpose, extracorporally or on the "back-table" technique, according to many researchers, simplifies and accelerates the technique of performing arterial blood flow when implanted into an organ, reduces the time of surgery, reduces ischemic and reperfusion damage.

Based on the above provisions, in contrast to the extracorporeal methods suggested by many researchers, we performed twenty-five reconstructive interventions inside the recipient's abdomen[8,14,15]. The recipient's common hepatic artery was cut off from the gastro-duodenal artery and preserved.

The deficit of donor organs is solved at the expense of donors with extended criteria, i.e. the population of donors older than 60 years, with widespread atherosclerosis of the abdominal aorta and its branches. The risk of arterial complications in this population will be naturally higher due to the threat of intima peeling or thromboembolism of the abdominal

atherosclerotic plaque. There are other difficulties: wide aortic secretion, aortic compression (in case of aortic atherosclerotic atherosclerotic peeling is possible). Previously performed operations, cause adhesions, obesity, also complicate the operation. Technical difficulties are often related to the condition of the recipient's arterial walls. Persistent vascular spasm, small arterial diameter, atherosclerotic damage to arterial walls, weak arterial flow, early endovascular interventions (arterial embolization of the liver, thrombectomy, etc.) or preoperative thrombosis may require other arterial reconstruction methods. The most common is to perform anastomosis directly between the recipient's aorta and the donor's ventricular stem using the donor's iliac vessels[4]. However, such operations are accompanied by a reliably high percentage of thrombosis[21]. If the recipient's hepatic arteries are in poor condition, some researchers suggest using anastomosis with the splenic artery or with the recipient's ventricular trunk[4].

The diameter of the reconstructed vessels also affects the outcome of arterial reconstruction, for example, the diameter of the artery less than 3 mm is also associated with a real threat to the thrombosis[18]. Even magnifying optics and microsurgical techniques do not save from vascular thrombosis. For example, in liver lobes transplantation, if the artery diameters are much smaller than the whole organ transplantation, but not all researchers admit it[6, 19]. End-to-end anastomoses are more prone to thrombosis than those obtained with Carrel's site, as it is almost always possible to expand and strengthen it [19]. Our experience has also shown that end-to-end sites in reconstructed vessels also improve anastomosis permeability. The results of arterial reconstructions will be better where they are performed more often. In centres performing less than 30 transplants per year, the complication rate is higher than in clinics with greater transplantation activity[22].

Approximately 40% of donor livers have a variable branching of the arterial channel, which requires reconstructive interventions before implantation. The presence of variable arterial anatomy and the need for reconstructive interventions on the recipient's vessels and donor liver, which can also be affected by atherosclerosis, increase the probability of arterial thrombosis of the liver transplant arteries many times[22]. Good arterial blood flow permeability largely depends on the choice of arterial reconstruction method.

The method of liver transplantation according to Belghiti is now recognized as the most optimal one and is often performed in different liver transplantation centers[16]. To reduce the time of thermal ischemia during implantation B. I. Shumakov (1995), T. Soliman (2003), W. Andraus (2013), proposed extracorporeal reconstructive interventions on the arteries of the liver transplant, when outside the recipient's abdominal cavity on the "back-table" of two and even three arteries, a single source of arterial blood supply is received[11,12,15,17]. But as our own experience has shown, this does not provide all the optimal conditions for both the operation itself and the risk of thrombosis of the reconstructed arterial channel.

The Belghiti liver transplant technique provides the convenience of performing kavavaval and venous anastomosis. The reconstructed arterial channel of the liver transplant to the "back-table" including the aberrant arteries, e.g. through the spleen cult or the upper mesenteric artery always provides an excess length that can be used to perform anastomosis even with the aorta[8]. Traditionally, however, the hepatic artery is connected after the blood flow has been restored and the "pulse wave" significantly increases the excess of the reconstructed arterial graft system. This also changes the angle of inclination of the performed anastomosis and the twisting of the artery along the axis, increasing intravascular resistance and contributing to clot formation.

The method of restoration of arterial circulation inside the recipient's abdominal cavity after switching on the venous blood flow does not have these drawbacks. The main blood flow through the common hepatic artery is immediately restored and provides arterial blood to the main part of the biliary graft system. Additional anastomosis is then performed with the right or left aberrant arteries, connecting them to an alternative source from the upper mesenteric artery.

Taking into account that the surgical technique of reconstructed interventions affects the thrombosis frequency and increases the risk

of complications, the presented technique is very important in our opinion, because it provides convenience of execution, does not prolong the time of thermal ischemia, increases the total volume of arterial blood to the organ and reliably guarantees the restoration of function after its transplantation[11,14, 19]. In this case, it is very important to take into account the functional characteristics of the patient's cardiovascular system, including the characteristics of his nutrition[23,24].

Conclusions

1. The presented method of blood circulation restoration at liver transplantation at abnormal structure of arterial channel of the liver transplant is performed inside the recipient's abdominal cavity. At first, blood flow is restored along the reconstructed common hepatic artery, after the right or left aberrant arteries liver transplant.

2. The technique provides the shortest route of the recipient's arterial blood to the liver transplant, through the upper mesenteric artery provides an alternative source of arterial blood supply from the aorta for which the transplant is additionally needed.

3. The new method of blood circulation restoration provides an opportunity to avoid the formation of "kinking" syndrome, in the occurrence of which the blood vessels are lengthened, the angulation and location of the blood vessel in relation to the grafts and other abdominal organs. This reduces the risk of thrombosis of the arteries of the transplanted liver.

Declaration of Interest

The authors report no conflict of interest.

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