https://doi.org/10.23873/2074-0506-2021-13-4-367-381

Emergency interventional endovascular treatment for early disorder of arterial blood flow in the liver graft

B.B. Gegenava[1,2], S.A. Kurnosov✉[1], Ya.G. Moysyuk[1],
N.N. Vetsheva[1], A.A. Ammosov[1]

[1]*Moscow Regional Research and Clinical Institute n.a. M.F. Vladimirskiy, 61/2 Schepkin St., Moscow 129110 Russia*;

[2]*Zhukovskaya City Clinical Hospital, 1 Frunze St., Zhukovskiy, Moscow region 140180 Russia*

✉Corresponding author: Sergey A. Kurnosov, Surgeon in endovascular X-ray diagnosis and treatment, Junior Researcher of the X-ray Endovascular Surgery Department of the Moscow Regional Research and Clinical Institute n.a. M.F. Vladimirskiy, sergey.kurnosov.88@mail.ru

Abstract

Introduction. *Liver transplantation is considered the most effective treatment for patients with end-stage liver disease. X-ray endovascular interventions show good results in the treatment of vascular complications after transplantation. The timing, indications and choice of treatment methods require clarification.*

Objective. *To evaluate the safety and efficacy of emergency X-ray endovascular interventions for arterial complications in the early period after liver transplantation.*

Material and methods. *In the period from October 2016 by July 2021, 88 liver transplants were performed. The graft was obtained from a posthumous donor in 75 cases, and from a living donor (right lobe of the liver) in 13 cases. Arterial complications were registered in 10 cases: thrombosis of the hepatic artery in 7 (8.0%), constriction in 3 (3.4%); 4*

patients underwent retransplantation due to thrombosis. This analysis included 6 patients aged 27 to 51 years, including 4 men and 2 women. In the early postoperative period (0-14 days), according to laboratory parameters, ultrasound Doppler, and computed tomography with a contrast agent, an impairment of the arterial blood supply of the graft was revealed, for which the patients underwent emergency X-ray image-guided surgical endovascular interventions.

Results. *Restoration of adequate arterial blood supply to the liver graft was achieved in all six patients. At the time of this writing, the graft function and patency of the hepatic artery were preserved at follow-up periods of 6, 11, 12, 22 (in two patients), and 26 months with a median of 17 months. Four patients developed biliary complications that required surgical correction.*

Conclusion. *X-ray image-guided endovascular interventions can be considered effective and relatively safe in the treatment of patients with arterial complications after liver transplantation. The period of graft arterial ischemia should be minimized as much as possible in order to prevent biliary complications.*

Keywords: orthotopic liver transplantation, *constriction* and thrombosis of the hepatic artery, X-ray image-guided endovascular interventions, endovascular revascularization, balloon angioplasty with stenting, splenic artery embolization

Conflict of interests Authors declare no conflict of interest

Financing The study was performed without external funding

For citation: Gegenava BB, Kurnosov SA, Moysyuk YaG, Vetsheva NN, Ammosov AA. Emergency interventional endovascular treatment for early disorder of arterial blood flow in the liver graft. *Transplantologiya. The Russian Journal of Transplantation.* 2021;13(4):367–381. (In Russ.). https://doi.org/10.23873/2074-0506-2021-13-4-367-381

ALT, alanine aminotransferase

AST, aspartate aminotransferase

CHA, common hepatic artery

CT angiography, computed tomographic angiography

DAPT, dual antiplatelet therapy

DCFM, Doppler colour flow mapping

EIGI, endovascular X-ray image-guided surgical intervention

EV, esophageal varices

GDA, gastroduodenal artery

GV, gastric varices

HA, hepatic artery

HAT, hepatic artery thrombosis

LGA, left gastric artery

LHA, left hepatic artery

LT, liver transplantation

NHA, native hepatic artery

PTCS, percutaneous transhepatic cholangiostomy

RHA, right hepatic artery

Ultrasonography, ultrasound examination

USDG, ultrasound Dopplerography

Introduction

Chronic liver diseases and primary liver cancer are one of the most vital public health problems that affect more than 850 million people worldwide [1]. Liver transplantation (LT) is considered the most effective method of treating patients with end-stage liver disease [1-4]. Complications from the hepatic artery (HA) of the graft developing mainly at early stages after surgery may cause a disruption or cessation of arterial perfusion and pose a high risk of graft failure, biliary and pyo-

septic complications, patient death, and often dictate the need for liver retransplantation [3, 5-8]. The incidence of serious arterial complications, including constriction and thrombosis of the graft arteries, ranges from 2% to 15% [8, 9].

HA constriction after LT can lead to graft ischemia and hepatic artery thrombosis (HAT), which remains one of the most common and dangerous post-LT vascular complications.

The HAT incidence ranges from 2.5% to 12% in various sources [1, 2, 6, 7, 10-13]. The proportion of HAT makes from 50% to 65% of all vascular complications after LT [6, 12, 13]; in adults, its incidence ranges from 2% to 8% with a median of 4.4% [2, 5, 6, 9, 10, 14]. According to the time of their development, HAT can be divided into early and late having different clinical manifestations and requiring different treatment methods. According to available classifications, thromboses occurring in the period from the first 2 weeks to the first 3 months after LT are referred to early ones. [2, 9, 12]. Early HAT is associated with more aggressive clinical manifestations and marked laboratory abnormalities, a higher risk of graft loss, and a higher mortality rate compared to late thrombosis [2, 5]. Late HAT can be diagnosed months or years after transplantation [5] and may be manifested by a gradual deterioration of graft function, liver abscesses, and recurrent cholangitis, or it may not manifest itself clinically and may be accidentally identified during examination.

Dynamic ultrasound Dopplerography (USDG) is the primary method of screening and early diagnosis of HAT. The diagnosis can be confirmed by computed tomography or magnetic resonance imaging (MRI) with contrast. HAT-related mortality after LT reaches 54.5%. Liver retransplantation may be required after HAT in 75% of cases [13, 15].

Options for correction of arterial complications after LT include open surgical and endovascular revascularization, thrombolytic therapy,

urgent retransplantation, and, extremely rarely, a conservative anticoagulant therapy [5, 14]. The success rate of open surgical revascularization, according to available sources, ranges from 10% to 55% [5].

Endovascular X-ray image guided surgical interventions (EIGIs) have shown good results in the treatment of arterial complications after LT, especially with stenosis development [1, 7, 8, 11, 13, 16, 17]; the immediate success rate ranges from 46 to 68% [5]. Urgent EIGI in the cases of early HAT within the first week after LT can reach a 81% success rate and can significantly reduce the risk of graft loss and the need for retransplantation. Potential complications such as extravasation, perforation, dissection, pseudoaneurysm formation, and retrombosis of the liver arteries can also occur during EIGI. The risk of such complications ranges from 5% to 19% [12].

Selective (intra-arterial) thrombolysis, mechanical recanalization, thromboaspiration, isolated angioplasty or angioplasty with HA stenting, and splenic artery embolization are less invasive alternatives to surgery and retransplantation for arterial problems occurring early post-LT and become more widely used in clinical practice [3, 6, 8, 12, 14, 18, 19]. The timing, indications, and choice of EIGI methods and algorithms need to be specified.

The study objective was to evaluate the safety and efficacy of emergency EIGI for arterial complications in the early period after LT.

Material and methods

In the period from October 2016 to July 2021, 88 LT were performed in our center. The graft was obtained from a postmortem donor in 75 cases, and from a living donor (right lobe of the liver) in 13 cases. Arterial complications were registered in 10 cases: HAT in 7 (8.0%),

constrictions in 3 (3.4%). Due to early HAT, retransplantation was performed in 4 patients without attempting EIGI.

The present analysis included 6 patients aged 27 to 51 years, including four men and two women. In the early postoperative period after LT, the laboratory test results, USDG and CT angiography findings in patients suggested an impaired arterial blood supply to the graft, for which 8 EIGIs were performed (3 in one of the patients). The baseline clinical and demographic characteristics of patients and LT surgery features are presented in Table 1.

Table 1. Characteristics of patients, operations and complications of liver transplantation

Pt No.	Patient, gender, age	Diagnosis	Donor and graft type	Arterial reconstruction*	Complication, timing of its identification
1	E., man, 46 years old	Cirrhosis of mixed etiology (HCV, alcoholic) Child-Pugh class B (Score 9), MELD 20, portal vein thrombosis, portal hypertension, grade I-II hepatic encephalopathy. History of splenectomy	Cadaveric, whole liver	CHA/LPA	Constriction of HA in the anastomosis area, 12th day
2	M., man, 27 years old	Liver cirrhosis as a result of progressive familial intrahepatic cholestasis of type 3, Child-Pugh class B (Score 8), MELD 15, portal hypertension syndrome (grade 1-2 EV, splenomegaly, ascites)	Cadaveric, right lobe (split). Retransplantation	RHA/CHA	HA thrombosis, 14th day
3	K., man, 46 years old	Liver cirrhosis as a result of chronic viral hepatitis (HDV), Child-Pugh class B (Score 9), MELD 15, EV	Cadaveric, whole liver	CHA/NHA	Constriction of CHA, "kinking", 2nd day

4	R., man, 42 years old	Hepatic cirrhosis of viral etiology (HBV, HDV), Child-Pugh class A (Score 5), MELD 10, portal hypertension syndrome (grade 2 EV, splenomegaly)	Related, right lobe	RHA/RHA	HA thrombosis in the anastomotic area, 1st day
5	G., woman, 51 years old	Hepatic cirrhosis of viral etiology (HBV, HDV), Child-Pugh class C (Score 9), MELD 16, portal hypertension syndrome (grade 1 EV, splenomegaly, ascites)	Related, right lobe	RHA/RHA, Intraoperative thrombosis, venous autoplasty	HA thrombosis in the anastomotic area, 1st day
6	S., woman, 46 years old	Grade IV congenital liver fibrosis, cirrhosis, Child-Pugh class B (Score 7), MELD 14, portal hypertension syndrome (grade 2 EV, grade 3 GV). Splenic artery embolization	Cadaveric, whole liver	CHA/LGA, Additional RHA/GDA Intraoperative thrombosis	Constriction of CHA and RHA, 21st day

*Note: End-to-end anastomosed arteries of the donor liver/recipient are stated. Details of the operation are given in the text. EV: esophageal varices; GV: gastric varices

Methods of diagnosis and treatment

After transplantation, ultrasound Doppler examination was performed twice in the first 12 hours, then once daily from the 1st to the 7th day, and on indications after the first week (if case of appearing laboratory and/or clinical signs of graft dysfunction), but, at least, once every 3 days. USDG was made on GE Logiq E (portable) or Philips Epiq 7 ultrasound systems with convex sensors of 1-5 MHz, according to a standardized protocol. HA was evaluated in B-mode, by Doppler colour flow mapping (DCFM), and the spectral analysis of blood flow; the examination report stated the maximum systolic velocity (Vs in cm/s) and the resistive index (RI is a calculated parameter).

CT angiography was performed on indications on a Phillips HOST-

5233 multislice X-ray computed tomograph (16 sections), followed by multiplanar reconstruction of the obtained image.

Diagnostic angiography and EIGI were performed according to indications on Phillips Allura Xper FD20 and Phillips Integris Allura 9C angiographs. Diagnostic and therapeutic operations were performed with the following tools:

- diagnostic and guidewire catheters;
- distal access catheters;
- coronary aspiration catheters;
- microcatheters;
- 0.014” and 0.035” guidewires;
- compliant balloon catheters;
- non-compliant balloon catheters (NC);
- balloon-expandable stents;
- spirals;
- contrast agent Omnipack 350 mg.

Results

Here we describe a clinical case series.

Clinical Case Report No. 1

LT surgery was performed with technical difficulties due to a marked adhesive process after previous laparotomies and peritonitis. The recipient's left hepatic artery (LHA) had to be used for anastomosis with the common hepatic artery (CHA) of the donor liver (a non-standard option).

According to USDG data, from the postoperative day 1, the signs of HA constriction were noted: Vs 4 cm/s, RI 0.3-0.4. CT angiography (on

postoperative day 12) revealed a narrowing of the graft CHA in the anastomotic area regarded as hemodynamically insignificant.

The patient was discharged on day 35 having satisfactory graft function. He was hospitalized after 3 months for an elevated body temperature to 38^0C, a moderate increase in the levels of liver enzymes and bilirubin. According to USDG, Vs was 56 cm/sec, RI was 0.3-0.4. An abdominal ultrasound examination identified abscesses of the liver right lobe, anastomotic stricture of the choledochus.

Ultrasound-guided percutaneous transhepatic cholangiostomy (PTCS) and the abscess cavity drainage were performed. Repeated CT angiography (Fig. 1) demonstrated the progression of HA constriction along the entire donor segment of the artery.

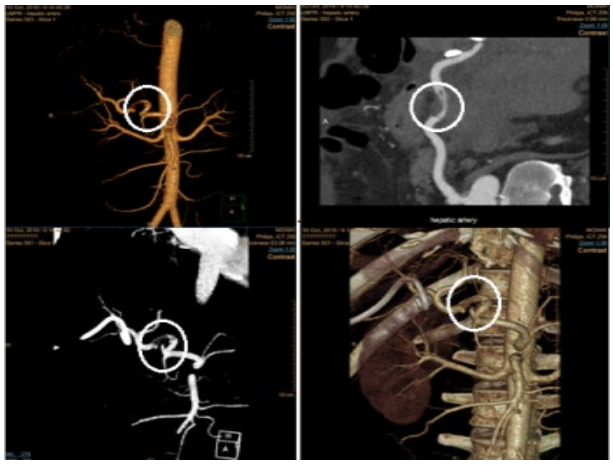

Fig. 1. CT-angiography 4 months after liver transplantation in Patient No. 1. Critical constriction of the hepatic artery (highlighted in a circle)

Angiography revealed a critical constriction of the HA lumen in the anastomotic area (postoperative day 132). Balloon angioplasty was performed, followed by a balloon-expandable stent implantation in the area of a residual contrast defect. At control angiography a complete stent expanding, its adequate positioning, and a non-occlusive spiral dissection

were visualized. Given a high risk of intraoperative complications, and a restored blood flow, it was decided to refrain from further intervention (Figure 2). To prevent stent thrombosis, antiplatelet monotherapy with clopidogrel, 75 mg/day, was administered that was discontinued after 12 months.

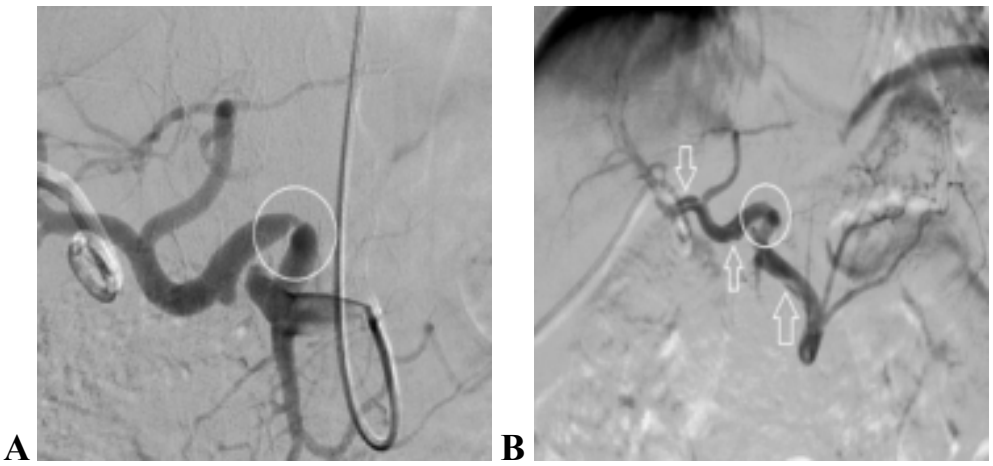

Fig. 2. Stages of endovascular treatment of Patient No. 1. (A) Critical constriction of the lumen in the anastomotic region (highlighted in a circle). (B) The lumen of the artery is restored, the positioning of the stent is adequate (highlighted in a circle), a non-occlusive spiral dissection is visualized (arrows)

At 26 months after stenting the HA, the laboratory parameters were within the normal range; at USDG, the HA was of the same diameter, patent, with persisting signs of post-stenotic blood flow: Vs 28 cm/sec, RI 0.48. External-and-internal drainage and the sessions of balloon dilation for the choledoch stricture were continued.

Clinical Case Report No. 2

On postoperative day 1, USDG records the main blood supply via HA: Vs 40 cm/sec, RI 0.49. After 2 weeks postoperatively, arrosive

bleeding from the hepatic artery occurred against the biliary peritonitis (due to biliodigestive anastomosis failure). During relaparotomy, RHA/CHA reanastomosis was performed. On the next day, a second relaparotomy and abdominal cavity antiseptic irrigation were urgently performed due to the development of a clinical pattern of septic shock. Intraoperatively, RHA thrombosis was identified. In conditions of an infected abdominal cavity, open thrombectomy was considered inappropriate. At doctors' consultation endovascular methods were recognized as the only option for restoring the arterial blood flow in the graft. The patient was urgently transferred to the angiography operating room.

Angiography showed a thrombotic occlusion of the HA. Mechanical recanalization of the occlusion with thrombi aspiration using a coronary aspiration catheter and balloon angioplasty were performed followed by the implantation of a balloon-expandable stent in the area of a residual contrast defect. A good angiographic result was obtained with restoring the antegrade blood flow in the liver graft (Fig. 3). To prevent stent thrombosis, a dual antiplatelet therapy (DAPT) with clopidogrel 75 mg and acetylsalicylic acid 100 mg once a day was administered.

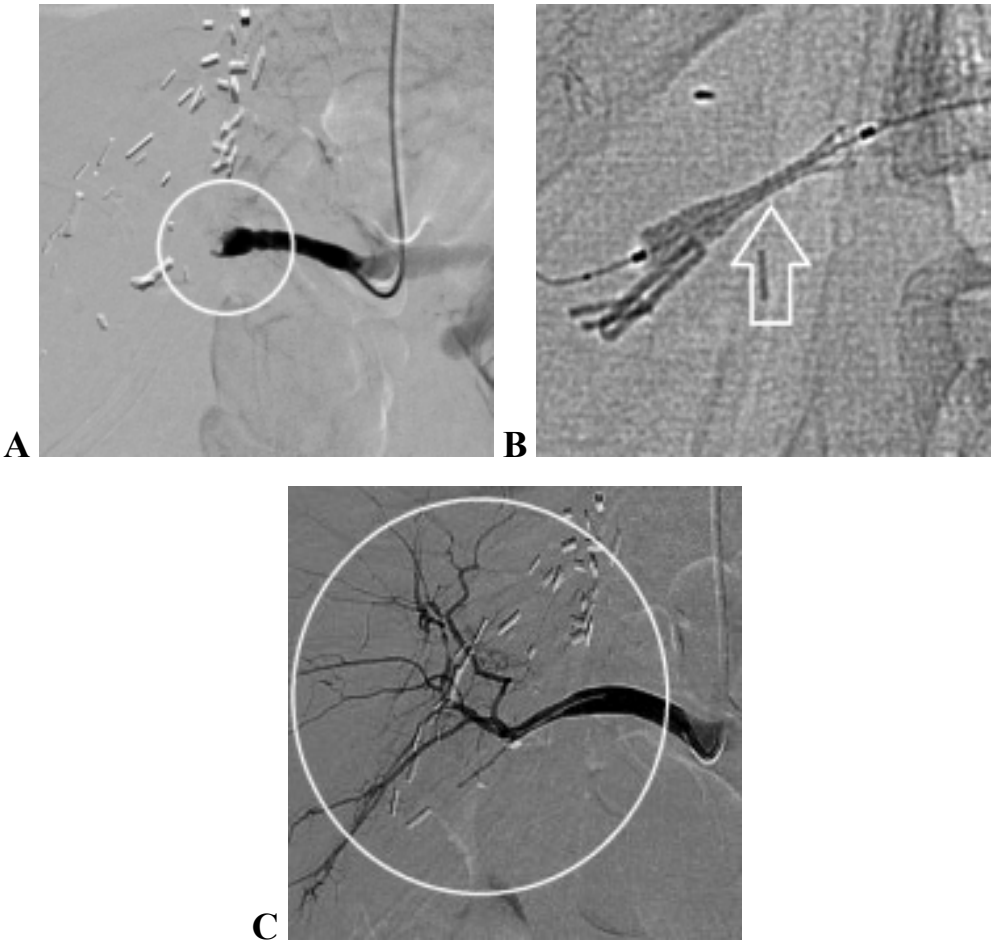

Fig. 3. Stages of endovascular treatment of Patient No. 2. (A) Hepatic artery thrombosis (circled). (B) Balloon angioplasty followed by implantation of a balloon-expandable stent into the residual contrast defect (arrow). (C) Good angiographic result with restoration of antegrade blood flow in the liver graft (circled)

UZDG in the early postoperative period showed the HA of up to 4 mm in diameter, Vs 70 cm/sec, RI 0.74. The blood test demonstrated the level of liver enzymes decreased to normal values. The patient was discharged from hospital on day 15 after EIGI.

At 22 months after EIGI, liver enzymes and bilirubin were within the target values. UZDG demonstrated the main blood supply via HA: Vs 63 cm/sec, RI 0.55.

Clinical Case Report No. 3

At USDG performed on postoperative day 2, the HA was visualized fragmentally: Vs 17 cm/sec, RI 0.5 that raised the suspicion of an impaired arterial blood flow.

Emergency angiography verified a pathological curving of the graft artery ("kinking") distal to the anastomosis with the lumen narrowing of over 70% with angiographic signs of severe peripheral angiospasm of the liver arteries, with a decreased arterial perfusion of the graft. An attempt was made to perform balloon angioplasty of the "kinking" zone, but the curving remained of the same degree. Then, 5 mg of verapamil was selectively injected into the HA (for the purpose of peripheral vasodilation). Control angiography showed a relief of vasospasm, the acceleration of blood flow, and improvement of liver graft perfusion (Fig. 4). To prevent thrombosis, a long-term DAPT with clopidogrel 75 mg and acetylsalicylic acid 100 mg once a day was administered.

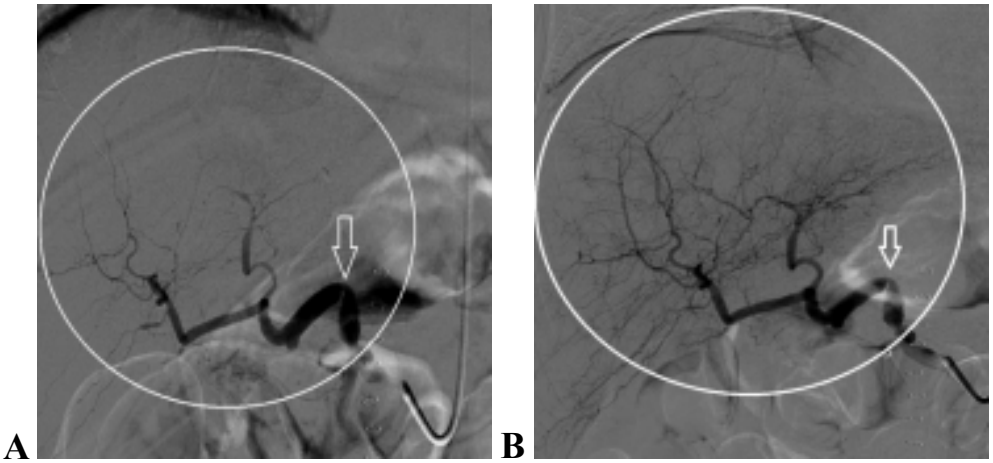

Fig. 4. Stages of endovascular treatment of Patient No. 3. (A) Significant kinking of the hepatic artery (arrow) and signs of depleted perfusion in the transplanted liver (highlighted in a circle). (B) The kink is in its original state (arrow), improved graft perfusion after selective administration of verapamil (highlighted by a dotted circle)

At USDG on day 1 after EIGI, the HA of up to 5 mm in diameter with the main blood supply was visualized; Vs was 45 cm/sec, RI was 0.56. At 22 months after LT, the graft function was good without any signs of arterial blood flow impairments or biliary complications.

Clinical Case Report No. 4

At USDG performed on postoperative day 1, no blood flow in HA was visualized, which was suspicious of HAT. A 100-fold increase in the level of aspartate aminotransferase (AST), and a 50-fold increase in alanine aminotransferase (ALT) from the upper limit of normal were noted in blood biochemistry test results.

Emergency angiography confirmed the HA thrombotic occlusion. Mechanical recanalization of occlusion with thrombi aspiration using a distal access catheter and balloon angioplasty were performed followed by the implantation of a balloon-expandable stent in the area of a residual contrast defect. The control angiogram shows a good angiographic result with restored antegrade blood flow in the liver graft (Fig. 5). To prevent stent thrombosis, DAPT with clopidogrel 75 mg and acetylsalicylic acid 100 mg once a day was administered.

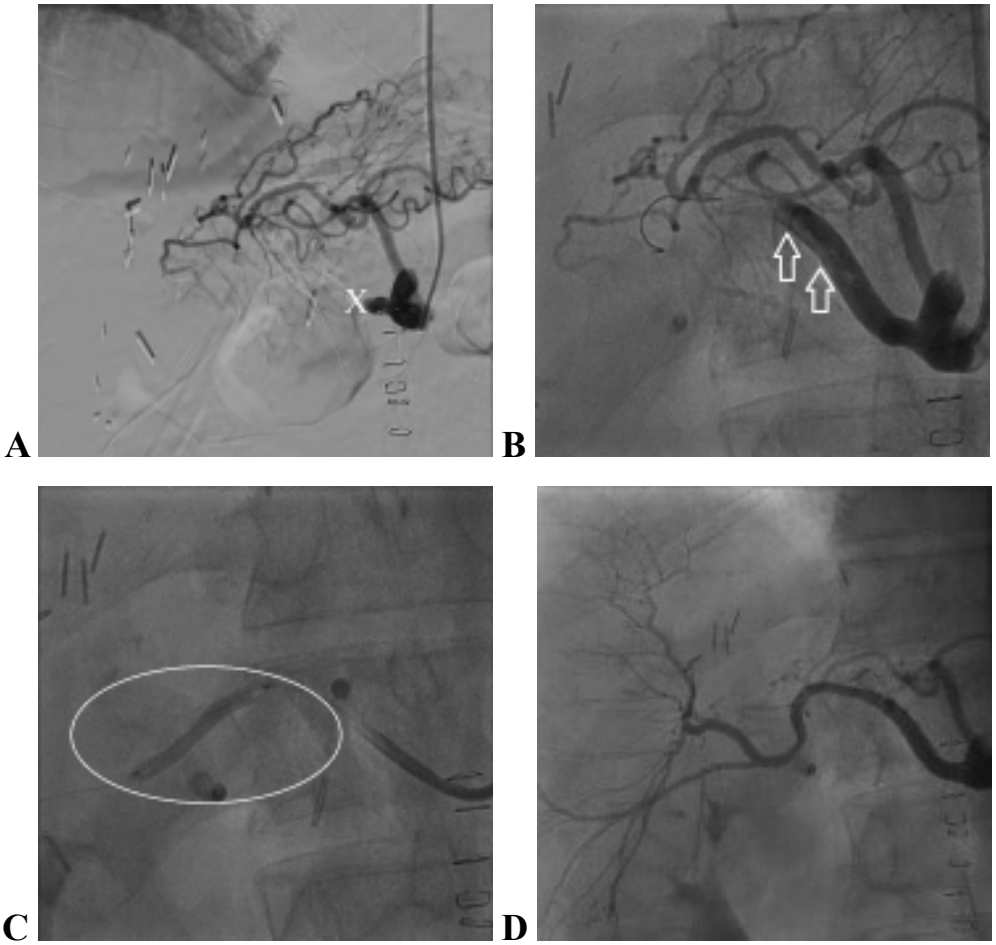

Fig. 5. Stages of endovascular treatment of Patient No. 4. (A) Hepatic artery thrombosis (cross). (B) Recanalization of occlusion with mechanical aspiration of thrombi using a distal access catheter (two arrows). (C) Balloon angioplasty with stenting of the residual contrast defect zone (highlighted by an oval). (D) Good angiographic result with restoration of antegrade blood flow

UZDG performed on day 1 after EIGI showed the main blood supply via the HA, Vs was 69 cm/sec, RI was 0.81. The blood biochemistry suggested a positive trend in significantly decreasing liver enzymes. The patient was discharged from hospital on day 32 after EIGI.

At 4 months after LT, the patient was re-hospitalized with complaints of pruritus and jaundice. At USDG, the HA of up to 4 mm in diameter was visualized with a main blood supply; Vs was 44 cm/sec, RI

was 0.68. Abdominal ultrasonography suggested the dilation of intrahepatic ducts with signs of biliary hypertension. Blood biochemistry showed increased liver enzymes. The patient underwent X-ray image guided percutaneous external drainage of the bile ducts, and the stricture of the biliobiliary anastomosis was verified. Two months later, a reconstructive surgery of hepaticojejunostomy was performed.

Twelve months after HA stenting and 6 months after hepaticojejunostomy, the levels of liver enzymes and bilirubin were within the normal ranges. At UZDG, HA of 4 mm in diameter was visualized with the main blood supply: Vs 56 cm/sec, RI 0.7. DAPT was discontinued.

Clinical Case Report No. 5

During LT surgery, significant vascular tension was formed in the area of the superimposed anastomosis between the graft right hepatic artery (RHA) and the recipient's RHA due to an insufficient length. At intraoperative USDG, a questionable arterial blood flow was visualized with further thrombosis. Reanastomosis was formed between the graft artery and the recipient's CHA using a venous autograft of 3 cm long tailored from the inferior mesenteric vein. Satisfactory blood flow was confirmed by palpation and intraoperative ultrasound. At UZDG performed on postoperative day 1, no blood flow in the HE was visualized, so HAT was suspected.

Emergency angiography revealed a thrombotic occlusion of the recipient's HA and venous autograft. Mechanical aspiration of thrombi was undertaken using a distal access catheter, balloon angioplasty of the recanalized segment was performed, followed by the implantation of balloon-expandable stents in the area of contrast defects. Control angiograms showed good antegrade blood flow through the liver graft

arteries (Fig. 6). To prevent stent thrombosis, DAPT with clopidogrel 75 mg and acetylsalicylic acid 100 mg once a day were administered.

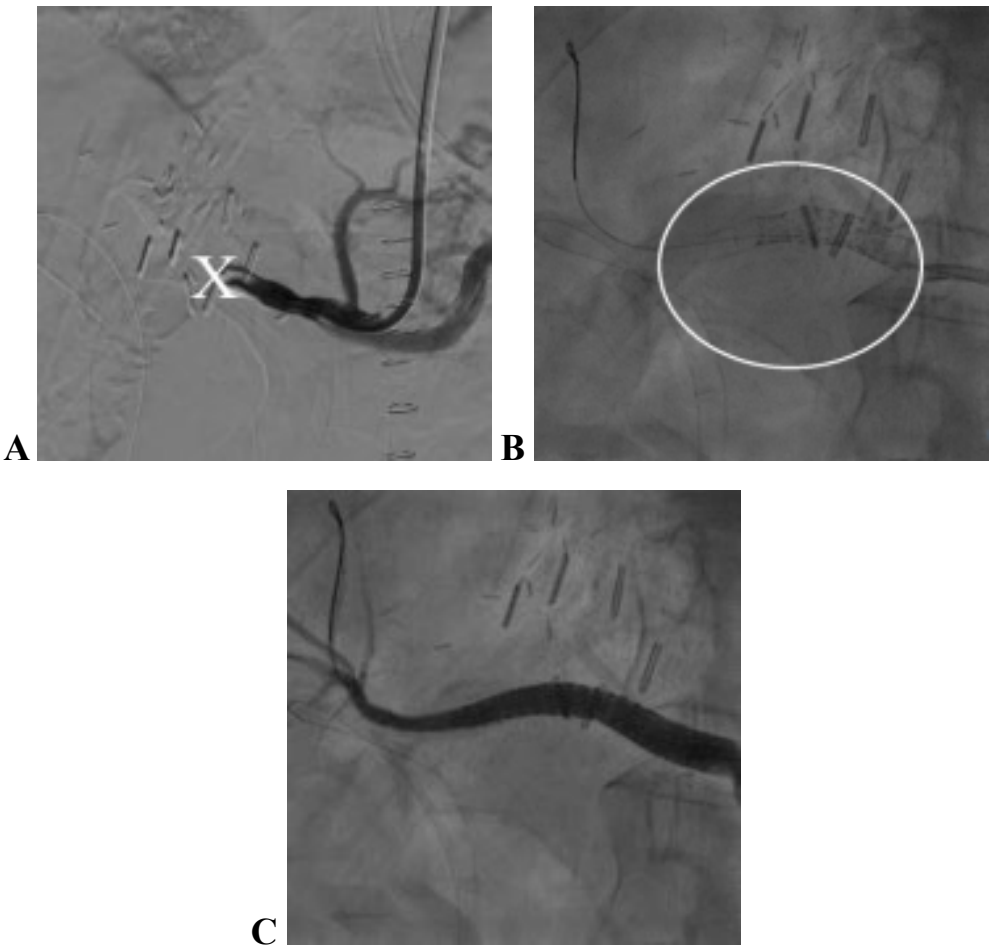

Fig. 6. Stages of endovascular treatment of Patient No. 5. (A) Hepatic artery thrombosis (cross). (B) Implantation of balloon-expandable stents into area of contrasting defects (highlighted by an oval). (C) Good angiographic result with restoration of antegrade blood flow in the liver graft

On day 2 after EIGI, a dynamic USDG revealed retrombosis.

Angiography revealed thrombotic occlusion in the distal edge of the stent. Occlusion recanalization was performed with the support of a balloon catheter with multiple balloon angioplasty and the implantation of a balloon-expandable stent. A good antegrade blood flow was achieved

(Fig. 7). Due to possible intolerance of clopidogrel, the drug was replaced with ticagrelor (90 mg twice daily).

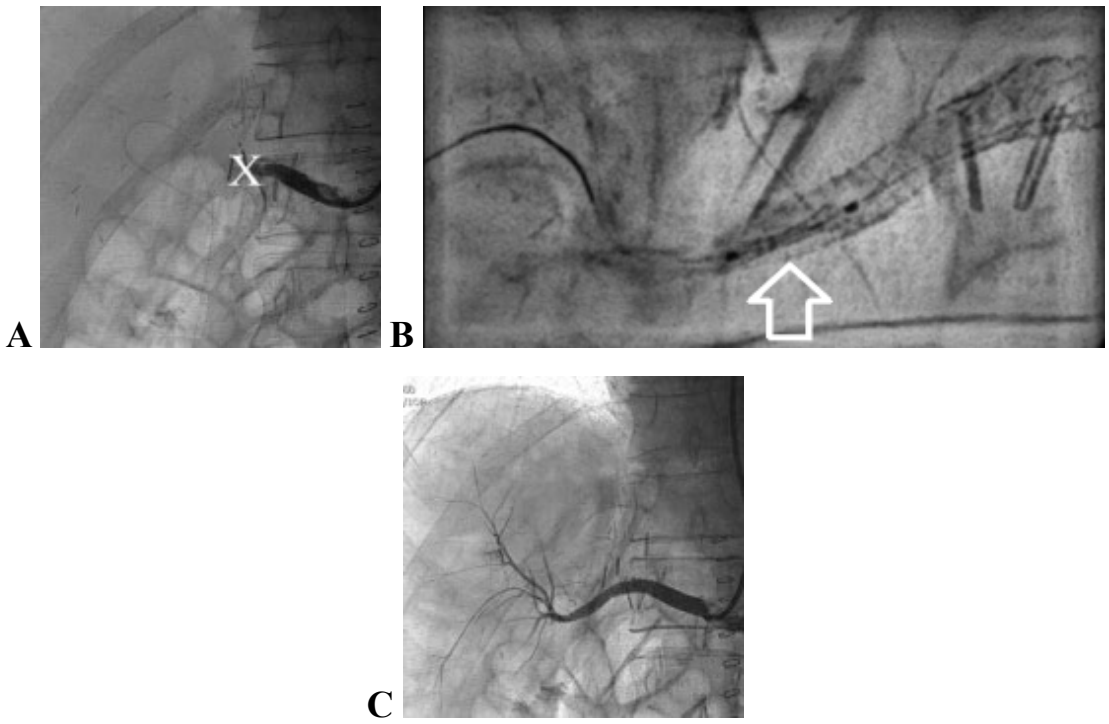

Fig. 7. Stages of endovascular treatment of Patient No. 5. (A) Recurrent Hepatic artery thrombosis (cross). (B) Implantation of a balloon-expandable stent into area of the contrasting defects (arrow). (C) Good antegrade blood flow through the liver graft arteries

On the following day, the patient showed a progressive increase in ALT and AST levels; USDG demonstrated a decrease in Vs from 50 cm/sec to 20 cm/sec. A decision was made to perform a control angiography (the third one in a row).

Angiography showed a thrombotic subocclusion of the stented area. Mechanical recanalization of subocclusion was performed with multiple balloon angioplasty and subsequent implantation of a balloon-expandable stent. The angiogram showed the restored lumen of the liver graft artery. In order to prevent a steal syndrome, the splenic artery was embolized

with ejected spirals. After the splenic artery occlusion, a redistribution of blood flow was noted: a good antegrade blood flow via the arteries of the liver graft was achieved (Fig. 8).

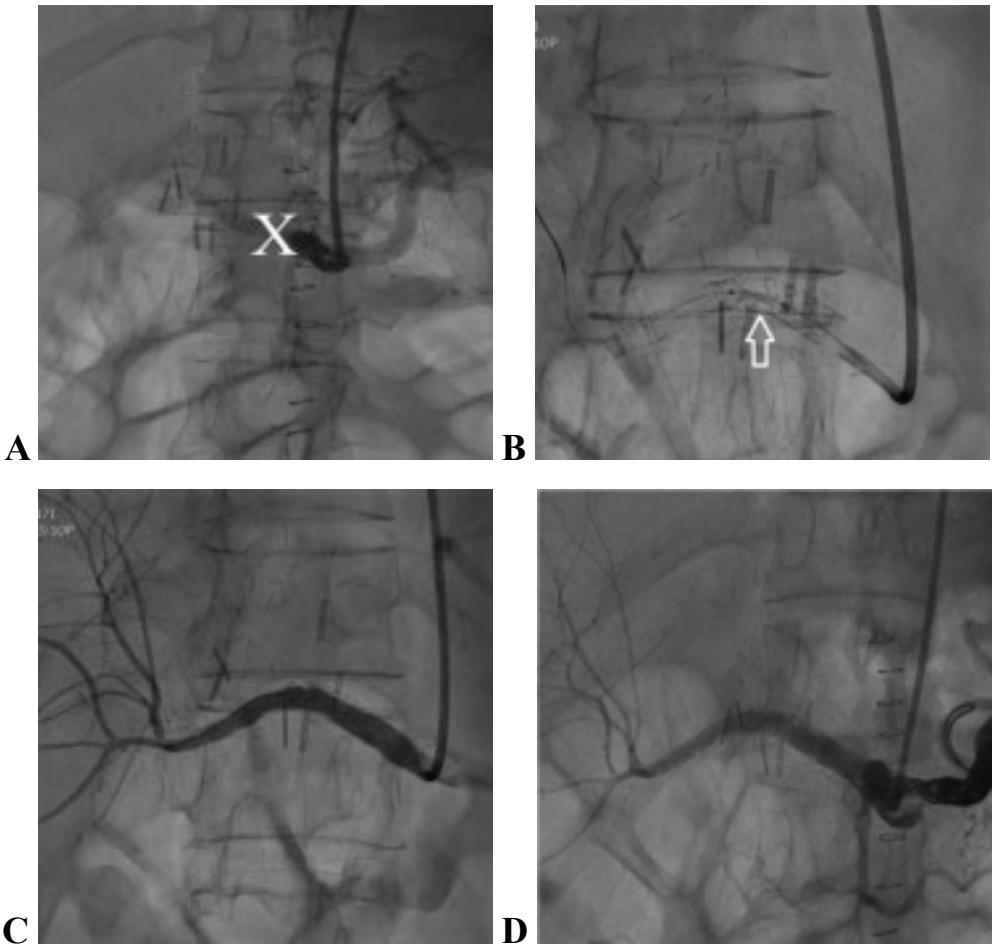

Fig. 8. Stages of endovascular intervention in Patient No. 5. (A) Thrombotic subocclusion of the stented area. (B) Implantation of a balloon-expandable stent into area of the contrasting defects. (C) Restoration of antegrade blood flow in the liver graft. (D) Embolization of the splenic artery with ejected coils to prevent steal syndrome

USDG on postoperative day 7 showed the main blood supply in the HA, Vs was 57 cm/sec, RI was 0.77. The patient was discharged from hospital on day 20 after the third EIGI.

After 2 months, a percutaneous biloma drainage was performed under ultrasound guidance.

The examination at 8 months postoperatively (including MR cholangiography, endoscopic retrograde cholangiopancreatography) revealed a partial incompetence of the hepaticocholedochoanastomosis and bilioduodenal fistula in the absence of clinical manifestations. Endoscopic stenting was performed.

At 11 months after three consecutive EIGI, the USDG showed the main blood supply, Vs was 70 cm/sec, RI was 0.54. The graft function was satisfactory.

Clinical Case Report No. 6

As part of preoperative preparation, the patient underwent splenic artery embolization in order to prevent steal syndrome after LT. Arterial reconstruction during transplantation had its own peculiarities. The donor liver had an additional RHA, which was anastomosed with the gastroduodenal artery (GDA) "end to end" at the "back-table" stage. During LT, a primary anastomosis was formed between the donor organ's CHA and the recipient's CHA. As a result of the intima dissection, thrombosis of the latter occurred intraoperatively. A new arterial anastomosis was formed between the recipient's LGA of 4mm in diameter and the graft's CHA.

According to USDG on postoperative day 1a HA with a caliber of up to 4 mm with Vs 30 cm/sec, RI 0.6. According to laboratory data, there was a tendency to the decrease in liver enzymes and bilirubin. Taking into account a non-standard arterial reconstruction, the patient was administered anticoagulant and antiplatelet therapy for 2 weeks. After 2 weeks of an uneventful postoperative course, there was an increase in total bilirubin from 80 mmol/L to 220 mmol/L. The differential diagnosis

was made to distinguish between the rejection crisis from an impairment of arterial blood flow in the graft. According to USDG data, Vs was 59 cm/sec, RI was 0.5, so a stenotic lesion of the HA could not be excluded and was confirmed by CT angiography later (Fig. 9). Based on the results of the examinations, a decision was made to perform selective celiacography.

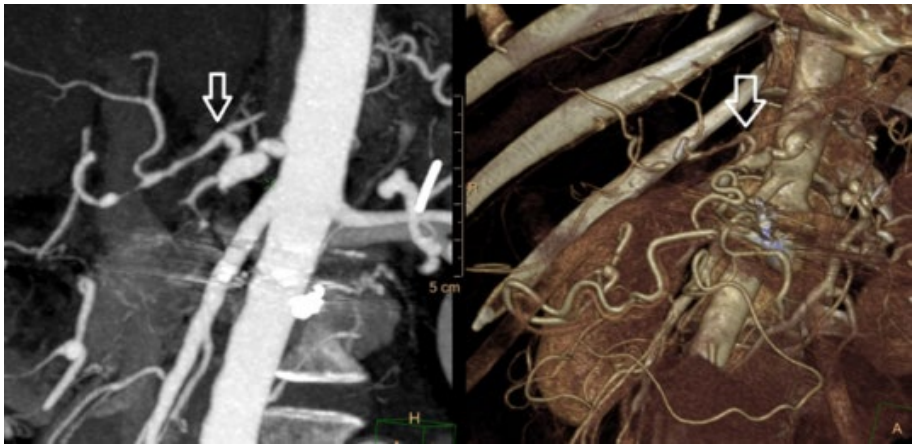

Fig. 9. CT-angiography 3 weeks after liver transplantation. The lumen of the celiac trunk is uneven with constrictions and dilations of 2.6 to 8.5 mm in diameter and the presence of a convoluted course; the anastomosis between the left gastric artery of the recipient (white arrow) and the common hepatic artery of the donor liver is patent. There are critical constrictions throughout the common hepatic artery and gastroduodenal artery of the graft.

Angiography showed tortuosity of the celiac trunk with an uneven caliber. The graft artery caliber was uneven with constrictions of up to 70-80% in the graft's CHA and GDA. A decision was made to stent CHA, GDA, and accessory RHA. Balloon angioplasty of all affected segments was performed. A balloon-expandable stent was implanted in the area of residual constrictions with optimization of NC expanding by a balloon catheter. After the re-insertion of the guidewire from the LHA, the

kissing-balloon dilation of the HA bifurcation with two balloon catheters was performed. On control angiograms, a lumen patency of the CHA and its branches was completely restored; no signs of residual constrictions in the area of stent implantation and dissections along the edges of the stent were detected. Good antegrade blood flow through the liver graft arteries was achieved (Fig. 10). Dual antiplatelet therapy with ticagrelor 90 mg twice a day and acetylsalicylic acid 100 mg once a day was administered.

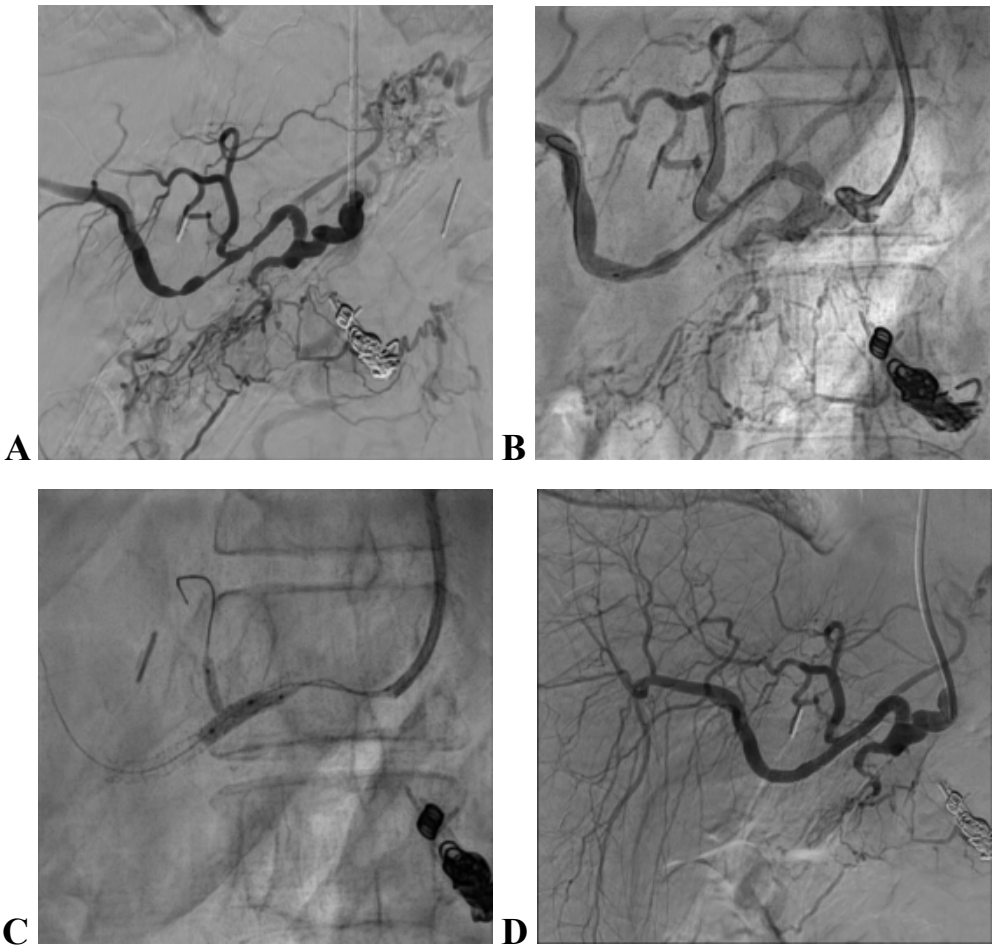

Fig. 10. Stages of endovascular intervention in Patient No. 6. (A) Constriction up to 70-80% in the common hepatic artery and right hepatic artery. (B) Insertion and positioning of the stent in the area of residual constrictions after balloon angioplasty. (C) Balloon-kissing dilatation of the common hepatic artery bifurcation. (D) Good angiographic result in the graft arteries

In the postoperative period, the USDG of the hepatic artery showed the main blood supply, Vs 61 was cm/sec, RI was 0.7. Laboratory data demonstrated normalization of ALT, AST, and bilirubin. At 6 months after EIGI, the USDG showed good velocity and spectral characteristics of the blood flow through the liver arteries. Laboratory parameters were within normal ranges.

Discussion

The hepatic artery complex reconstructions in a graft from either postmortem or live donors are highly likely to be associated with constrictions and thromboses in the early postoperative period, which may frequently cause the graft death or the development of serious complications, primarily biliary and septic ones (10%-40%) [4, 20, 21]. Non-standard arterial reconstructions took place in our Cases No. 1, 3, 5, 6.

In the analyzed group of patients, various impairments of arterial blood flow in the transplanted liver were diagnosed within the first 14 days after transplantation thanks to the applied strict ultrasonography/USDG monitoring protocol adopted at the center.

Ultrasound examination reveals thrombosis and constriction of the hepatic artery after LT in 92% of cases [22]. However the bans associated with the limited acoustic window after surgery and also with anastomosis formation peculiarities and the anatomy of donors and recipients, often lead to a lack of HA visualization in DCFM mode in a typical location (anterior to the portal vein when you scan through the right intercostal spaces), and do not allow establishing the correct angle (up to 60^0) to measure the velocity values [23]. To avoid false positive results that may arise in diagnosing vascular complications due to the lack of the arterial spectrum registration, it is necessary to additionally train specialists conducting the liver graft ultrasonography examinations and, in doubtful

situations, always seek the interpretation of ultrasonography findings from two specialists.

In Cases No.4 and No. 5, HAT was suspected in an absent HA visualization in the DCFM mode during repeated studies as soon as on postoperative day 1. Meantime, to exclude an operator-dependent bias, an absent blood flow at imaging had to be confirmed by two experts. In order to reduce the graft total arterial ischemia time, CT angiography to verify the diagnosis was not used. The diagnosis of HAT was confirmed at emergency angiography that was immediately converted to EIGI.

Well-known criteria for post-stenotic blood flow, the so-called "tardus-parvus", which can arise suspicion of arterial problems, include a decreased peak systolic velocity lower that 48 cm/s, a decreased resistive index down 0.5 or lower, an increased systolic acceleration time of over 0.08 seconds (this parameter was not reflected in our protocol, it was evaluated subjectively). One should also remember that low blood flow velocities in the HA may be secondary to vasospasm or low cardiac output Dynamic ultrasonography with examinations sometimes performed three times a day may help to solve the problem. With this algorithm, you can avoid an additional CT scanning and start the endovascular treatment stage without wasting time. Localization of hemodynamically significant constriction may be different. The area of arterial damage is possible throughout from both the graft side and the recipient side, as well as in the areas of anastomosis [15].

In patients No. 1, 3, and 6, the decreased resistive index and the registered tardus-parvus blood flow type indicated Doppler ultrasonographic signs of HA constriction/thrombosis. The diagnosis was confirmed by CT angiography. A 4-month delayed EIGI in patient No. 1 apparently caused the development of severe ischemic cholangiopathy with the formation of anastomotic stricture and liver abscesses. Timely

coping with stenosis in patients No. 3, 6 made it possible to avoid the development of biliary complications.

Control USDG examinations after EIGI in 5 of our 6 patients immediately showed improvements in parameters in the form of an increase in the peak systolic velocity and/or an increase in vascular resistive indices. Meanwhile, in two patients, the values of vascular resistive indices were higher than normal; however, with dynamic follow-up they decreased to normal values. Only in one patient, No. 1, Doppler criteria after EIGI remained below reference values, indicating the persistent HA stenosis. The results of HA Doppler sonography after LT in the period before and after EIGI and in the long-term postoperatively are presented in Table 2.

Table 2. Hepatic artery Doppler sonography parameters in dynamics in patients after liver transplantation and X-ray image-guided endovascular intervention

Patients	**Patient No. 1**		**Patient No. 2**		**Patient No. 3**		**Patient No. 4**		**Patient No. 5**		**Patient No. 6**	
Parameters	Vs (cm/s)	Ri	Vs (cm/s)	Ri	Vs (cm/s)	Ri	Vs (cm/s)	Ri	Vs (cm/s)	Ri	Vs (cm/s)	Ri
Postoperative day 1	84	0.40	40	0.49	65	0.50	0	-	22	0.40	30	0.60
Before EIGI	Postoperative day 132		Postoperative day 14		Postoperative day 2		Postoperative day 1		Postoperative 1o		Postoperative day 21	
	66	0.40	0	-	17	0.50	0	-	0	-	59	0.50
After EIGI	Postoperative day 133		Postoperative day 15t		Postoperative day 3		Postoperative day 2		Postoperative day 7		Postoperative day 23	
	51	0.47	70	0.74	45	0.56	69	0.81	57	0.77	61	0.7
Long-term results	26 months postoperatively.		22 months postoperatively		22 months postoperatively		12 months postoperatively		11 months postoperatively		6 months postoperatively	
	28	0.48	63	0.55	63	0.61	56	0.70	70	0.54	47	0.64

Endovascular revascularization in our cases included a combination of techniques:

- Mechanical catheter aspiration of thrombi was performed in 3 patients;

- Transluminal balloon angioplasty with stenting in 5 patients;
- Balloon angioplasty without stent implantation in one patient;
- Selective antispasmodic drug administration for vasodilation and improvement of graft perfusion was performed in one patient.
- Revascularization was combined with splenic artery embolization to prevent steal-syndrome in one patient.

One patient had an intraoperatively occurred non-occlusive spiral dissection without compromising blood flow, and the tactics of conservative therapy and dynamic follow-up were chosen. No other complications were seen during EIGI.

No relapses of arterial blood supply impairments to the liver graft after endovascular revascularization were observed in the follow-up period from 6 to 26 months, which can be regarded as a favourable result comparable to available literature data. The hepatic artery patency after the endovascular treatment in the volume of balloon angioplasty without stent implantation was 70%, 60%, 50%, and 44% after 1, 3, 6, and 12 months, respectively [1].

Stent implantation in the constricted area of the HA after LT is a safe and effective intervention. Drug-coated stents (DCS) show better patency-related results after LT compared to bare-metal stents stents (BMS) [14, 17]. D. Fleck et al. reported of DCS patency in the hepatic artery to be 62% at 1, 2, and 3 years. And BMS patency made 65%, 53%, and 45% at the same timepoints, respectively. A liver graft survival rate makes 100% after DCS implantation at 1, 3, and 5 years, and 97%, 87%, and 83% after BMS stenting at the same timepoints, respectively [17].

In the study, three patients underwent DCS implantation and in two patients BMS was implanted. Isolated balloon angioplasty was performed in the "kinking" area (Case No. 3).

At the time of writing this paper, all 6 patients have a patent HA and

satisfactory graft function at follow-up periods of 6, 11, 12, 22 (in two patients), and 26 months with a median of 17 months. Four patients developed biliary complications that required a surgical correction.

Conclusion

Dynamic Doppler ultrasound examination of liver graft arteries performed by an experienced specialist according to a standardized protocol makes it possible to timely suspect and detect vascular complications of the liver graft, and to make a decision on further therapeutic and diagnostic tactics as soon as possible.

X-ray image-guided surgical endovascular interventions can be considered effective and relatively safe in the treatment of patients with arterial complications after liver transplantation, starting from the first day of the postoperative period. The variety of techniques used, coupled with a wide range of angiographic tools, make it possible to correct graft perfusion in various clinical situations. Even if in the long-term after X-ray image-guided surgical endovascular intervention such complications as recurrent constrictions, late occlusion of the graft artery, and biliary complications may develop, an emergency X-ray-guided surgical endovascular revascularization helps avoiding a graft loss and patient death, and can become a bridge for planned liver retransplantation in the long-term period. The period of graft arterial ischemia should be minimized as possible in order to prevent biliary complications.

References

1. Devcic Z, Toskich BB, Livingston D, Crome KP, Lewis AR, Ritchie Ch, et al. Endovascular treatment of aortohepatic conduit stenosis following liver transplant. *Transplant Proc.* 2020;52(3):943–948. PMID:

32139279 https://doi.org/10.1016/j.transproceed.2020.01.017

2. Alconchel F, Martínez-Insfran LA, Cascales-Campos PA, Febrero B, Martínez-Alarcón L, Ríos A, et al. Impact of hepatic artery thrombosis on the success of a liver transplant because of hepatocellular carcinoma. *Transplant Proc.* 2020;52(2):559–561. PMID: 32029319 https://doi.org/10.1016/j.transproceed.2019.11.037

3. Roussel N, Otal P, Revel P, Zadro Ch, Meyrignac O, Mokrane F, et al. Intervention in the liver transplant patient. Chapter 38. In: *Image-guided interventions.* 3rd ed. Saunders; 2020. (A volume in Expert Radiology). p. 309–314.e3. https://doi.org/10.1016/B978-0-323-61204-3.00038-5

4. Granov DA, Polikarpov AA, Tileubergenov II, Zhuikov VN, Moiseenko AV, Sheralierv AR, et al. A case report of successful liver retransplantation in patient with early hepatic artery thrombosis complicated by bile ducts necrosis and sepsis. *Russian journal of transplantology and artificial organs.* 2019;3(21):76-83. (In Russ.). https://doi.org/10.15825/1995-1191-2019-3-76-83

5. Kok B, Dong V, Karvellas CJ. Graft dysfunction and management in liver transplantation. *Crit Care Clin.* 2019;35(1):117–133. PMID: 30447775 https://doi.org/10.1016/j.ccc.2018.08.002

6. Hamby BA, Ramirez DE, Loss GE, Bazan HA, Smith TA, Bluth E, et al. Endovascular treatment of hepatic artery stenosis after liver transplantation. *J Vasc Surg.* 2013;57(4):1067–1072. PMID: 23332988 https://doi.org/10.1016/j.jvs.2012.10.086

7. Rostambeigi N, Hunter D, Duval S, Chinnakotla S, Golzarian J. Stent placement versus angioplasty for hepatic artery stenosis after liver transplant: a meta-analysis of case series. *Eur Radiol.* 2013;23(5):1323–1334. PMID: 23239061 https://doi.org/10.1007/s00330-012-2730-9

8. Gastaca M, Gomez J, Terreros I, Izquierdo J, Ruiz P, Prieto M, et al. Endovascular therapy of arterial complications within the first week

after liver transplant. *Transplant Proc.* 2020;52(5):1464–1467. PMID: 32220478 https://doi.org/10.1016/j.transproceed.2020.02.075

9. Novruzbekov MS, Olisov OD. Vascular complications after orthotopic liver transplantation. *Transplantologiya. The Russian Journal of Transplantation.* 2017;9(1):35–50. (In Russ.). https://doi.org/10.23873/2074-0506-2017-9-1-35-50

10. Sakuraoka Y, da Silva Boteon APC, Brown R, Perera MThPR. Severe athe-rosclerosis of donor hepatic arteries is a salvageable condition in liver transplantation to optimise the graft utilisation: A case series and review of the literature. *Int J Surg Case Rep.* 2019;59:190 196. PMID: 31176087 https://doi.org/10.1016/j.ijscr.2019.05.048

11. Goto Y, Shirahama N, Sasaki S, Ishikawa H, Hisaka T, Ogata T, et al. Endovascular treatment for very early hepatic artery stenosis following living-donor liver transplantation: report of two case. *Transplant Proc.* 2018;50(5):1457–1460. PMID: 29880370 https://doi.org/10.1016/j.transproceed.2018.02.074

12. Goldsmith LE, Wiebke K, Seal J, Brinster C, Smith TA, Bazan HA, et al. Complications after endovascular treatment of hepatic artery stenosis after liver transplantation. *J Vasc Surg.* 2017;66(5):1488–1496. PMID: 28697937 https://doi.org/10.1016/j.jvs.2017.04.062

13. Le L, Terral W, Zea N, Bazan HA, Smith TA, Loss GE, et al. Primary stent placement for hepatic artery stenosis after liver transplantation. *J Vasc Surg.* 2015;62(3):704–709. PMID: 26054583 https://doi.org/10.1016/j.jvs.2015.04.400

14. Zhang H, Qian Sh, Liu R, Yuan W, Wang J-H. Interventional treatment for hepatic artery thrombosis after liver transplantation. *J Vasc Interv Radiol.* 2017;28(8):1116–1122. PMID: 28610742 ttp://doi.org/10.1016/j.jvir.2017.04.026

15. Forcella R Jr, Shahid MU, Kumar A, Shukla P, Riccardi J.

Endovascular treatment of post–orthotopic liver transplant hepatic artery complication: single transplant center review. *J Vasc Interv Radiol.* 2019;30 [Abstract International Symposium on Endovascular Therapy (ISET)-2019, (USA, Hollywood, Florida, January 26-29 2019)]:e11–e12.

16. Reese T, Raptis DA, Oberkofler CE, de Rougemont O, Györi GP, Gosteli-Peter M, et al. A systematic review and meta-analysis of rescue revascularization with arterial conduits in liver transplantation. *Am J Transplant.* 2019;19(2):551–563. PMID: 29996000 https://doi.org/10.1111/ajt.15018

17. Naidu S, Alzubaidi S, Knuttinen G, Patel I, Fleck A, Sweeney J, et al. Treatment of hepatic artery stenosis in liver transplant patients using drug-eluting versus bare-metal stents. *J Clin Med.* 2021;10(3):380. PMID: 33498286 https://doi.org/10.3390/jcm10030380

18. Granov DA, Tarazov PG, Polikarpov AA, Borovik VV, Rutkin IO, Tileubergenov II. Splenic artery embolization in patients undergoing orthotopic liver transplantation. *Russian Journal of Transplantology and Artificial Organs.* 2016;1(18):17–21. (In Russ.). https://doi.org/10.15825/1995-1191-2016-1-17-21

19. Moisyuk YaG, Gegenava BB, Ammosov AA, Porshennikov IA, Sidorenko AB, Pavlik VN, et al. Split liver transplantation in two recipients for urgent indications: an example and logistics of interregional cooperation. *Annaly khirurgicheskoy gepatologii=Annals of HPB Surgery.* 2020;4(25):71–84. (In Russ.). https://doi.org/10.16931/1995-5464.2020471-84

20. Piardi T, Lhuaire M, Bruno O, Memeo R, Pessaux P, Kianmanesh R, et al. Vascular complications following liver transplantation: A literature review of advances in 2015. *World J Hepatol.* 2016;8(1):36–57. PMID: 26783420 https://doi.org/10.4254/wjh.v8.i1.36

21. Granov DA, Maystrenko DN, Tarazov PG, Tileubergenov II,

Polikarpov AA, Moiseenko AV. Endovascular interventions in correction of arterial complications after orthotopic liver transplantation. *Journal diagnostic & interventional radiology.* 2021;15(1):51–58. (In Russ.). https://doi.org/10.25512/DIR.2021.15.1.05

22. Sanyal R, Zarzour JG, Ganeshan DM, Bhargava P, Lall ChG, Little MD. Postoperative doppler evaluation of liver transplants. *Indian J Radiol Imaging.* 2014;24(4):360–366. PMID: 25489129 https://doi.org/10.4103/0971-3026.143898

23. Delgado-Moraleda JJ, Ballester-Valles C, Marti-Bonmati L. Role of imaging in the evaluation of vascular complications after liver transplantation. *Insights Imaging.* 2019;10(1):78. PMID: 31414188 https://doi.org/10.1186/s13244-019-0759-x

Information about the authors

Boris B. Gegenava, Cand. Sci. (Med), Surgeon in endovascular X-ray diagnosis and treatment, Associate Professor of the Cardiovascular Surgery Department of the Faculty for Advanced Doctors' Training, the Moscow Regional Research and Clinical Institute n.a. M.F. Vladimirskiy; Head of the Department of Diagnostic and Treatment Techniques in X-ray Endovascular Surgery, Zhukovskaya City Clinical Hospital, https://orcid.org/0000-0003-2338-2120

20%, obtaining data for analysis, analysis of the data obtained

Sergey A. Kurnosov, Surgeon in endovascular X-ray diagnosis and treatment, Junior Researcher of the X-ray Endovascular Surgery Department of the Moscow Regional Research and Clinical Institute n.a. M.F. Vladimirskiy, https://orcid.org/0000-0001-6820-1536, sergey.kurnosov.88@mail.ru

30%, review of publications on the topic of the article, analysis of the data obtained, writing the text of the manuscript

Yan G. Moysyuk, Prof., Dr. Sci. (Med.), Head of the Department of Transplantology, Chief Researcher of the Moscow Regional Research and Clinical Institute n.a. M.F. Vladimirskiy, https://orcid.org/0000-0002-0002-9183, moysyuktrans@list.ru

30%, development of the study design, analysis of the data obtained, writing the text of the manuscript

Natalia N. Vetsheva, Dr. Sci. (Med.), Head of the Diagnostic Ultrasound Department, Professor of the Diagnostic Radiology Department of the Faculty for Advanced Doctors' Training, the Moscow Regional Research and Clinical Institute n.a. M.F. Vladimirskiy, https://orcid.org/0000-0002-9017-9432

15%, writing the text of the manuscript

Alexandr A. Ammosov, Cand. Sci. (Med), Head of the Department for Liver Transplantation and Surgery of the Moscow Regional Research and Clinical Institute n.a. M.F. Vladimirskiy, https://orcid.org/0000-0003-0667-2281

5%, collection of data for analysis

The article was received on August 20, 2021;
Approved after reviewing September 8, 2021;
Accepted for publication September 29, 2021