Modified Meso-rex Bypass With Umbilical Vein Recanalization and Intra-operative Stenting

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Abstract

Background

The aim of the study was to evaluate the usefulness of a novel modified Meso-Rex bypass surgical technique with umbilical vein recanalization and intraoperative stenting to treat portal vein cavernous transformation.

Methods

In total, 13 portal vein cavernous transformation patients underwent traditional Meso-Rex bypass surgery (Group A, *n*=8), modified Meso-Rex bypass without stent implantation (Group B, *n*=1) and modified Meso-Rex bypass with intraoperative stent implantation (Group C, *n*=4).

Results

In Group A, the bypass diameter was 2-6 mm (median 3.3 mm) and blood flow velocity 25-115 cm/s (median 75 cm/s) 1 month after Meso-Rex bypass surgery, with open bypass times of 0-59 months (median 16 months); 5 patients in this group developed postoperative Meso-Rex bypass occlusions. One patient in Group B needed a thrombectomy and stent implantation during a second surgery 2 days after the modified Meso-Rex bypass, because of bypass thrombosis and umbilical vein stenosis. In Group C, the average Meso-Rex bypass diameter was 5.5-6.5 mm (median 6 mm) and the bypass vessels remained open in all patients, with blood flow rates of 45-100 cm/s (median 76.5 cm/s) 1 month after Meso-Rex bypass, up to the endpoint (12-26 months, median 18 months). The rate of bypass occlusions in Group A and Group C were 25%, 0%; 25%, 0% and 50%, 0% at 1 month, 3 months and 1 year, respectively, after Meso-Rex bypass surgery.

Conclusions

Our novel modified Meso-Rex bypass approach for portal vein cavernous transformation treatment was effective with excellent long-term bypass patency.

Background

Portal vein cavernous transformation (PVCT) often results in portal hypertension followed by gastrointestinal bleeding and is mainly caused by portal vein thrombosis of unknown etiology [1, 2]. The purpose of surgical intervention for PVCT and prehepatic portal hypertension patients is to create a conduit between the superior mesenteric vein (SMV) or splenic vein (SpV) and the left portal vein (LPV), through which mesenteric and SpV blood circumvents the varicose region and flows into the liver. The Meso-Rex bypass (MRB) has become a commonly used method in which a graft between the SMV and the recessus of Rex bypasses the thrombosed portal trunk by using various shunt materials [3-6]. However, traditional MRB often requires dissection of the sagittal part of the portal vein (PV) [7], which can be challenging in patients with a severe adhesion. In addition, stent implantation or thrombolytic therapies have been deemed necessary to treat bypass embolizations or re-bleeding after MRB surgery [8-10]. Here we report a simpler modified MRB (mMRB) procedure comprised of end-to-end anastomosis of an allograft vein from the SMV to the recanalized umbilical vein (UV), with the intraoperative stent implantation from the opposite end covering the sagittal part of the portal vein-UV-allograft bypass. The aim was to evaluate this novel technique as a practical intervention procedure for the treatment of PVCT.

Methods

Patients

From November 2014 to June 2019, 13 patients with PVCT were enrolled in the study. Among them, 8 patients underwent traditional MRB (Group A), 1 patient underwent mMRB with UV recanalization without stent implantation (Group B) and 4 PVCT patients underwent the new mMRB approach with UV recanalization and intraoperative stent implantation (Group C). Data from these patients were retrospectively reviewed. The follow-up endpoint was set as May 2020. The ethics committee of Beijing Tsinghua Changgung Hospital approved the study and written informed consent was obtained from all participants.

Operative approach

The iliac vein, obtained from a donation after cardiac death, or the autologous right internal jugular vein were selected as the bypass vessels and great efforts were made to ensure that there were no residual tortuous or redundant blood vessels during the bypass procedure.

Group A: Rex recessus was treated as described in the literature (**Figure 1**). Ultrasonography confirmed that there was a fluent blood flow in LPV and the hepatic parenchyma around the Rex recessus was excised to expose the LPV. Sufficiently large incisions were made in the sagittal part of the PV to ensure fluent blood flow (at least 5 mm in diameter) and to avoid anastomotic stenosis. Anastomotic stoma selection at the distal end of the bypass vessel depended on whether it was possible to separate the stump of the PV where the SMV and SpV converged and the vessel was severed at the stump of the PV. If it was not possible to separate the stump of the PV where the SMV and SpV converged, then the SMV trunk or SpV trunk was selected (if the splenectomy was performed, only the SMV trunk could be selected), as close as possible to the confluence part. The sidewall of the SMV or SpV was blocked using a vascular blocking forceps and end-to-side anastomosis of the bypass vessel with the SMV or SpV was performed.

Groups B and C: Similarly, ultrasonography confirmed that there was fluent blood flow in the LPV. The stump of the ligamentum teres hepatis (the local hepatic parenchyma was excised only if the ligamentum teres hepatis was completely buried in the hepatic parenchyma and could not be directly separated) was separated and retained. The stump of the ligamentum teres near the root was transected, then the small vascular openings in the ligament and a small amount of blood overflow were seen, which was determined to be an umbilical vein with incomplete atresia. Using a vascular dilator (sequentially using 12-18F) to dilate through these vascular openings in the ligament, they opened up into the liver until the LPV, then blood outflow was observed and umbilical vein recanalization completed (**Figure 2A**).

During the recanalization process, the septum structure could be reached through the junction between the ligamentum teres and the PV, which had a 'sense' of resistance. The junction at this location was narrower than the pipes on both sides. End-to-end anastomosis of the bypass vessel with the recanalized umbilical vein was performed using a 5-0 prolene suture (**Figure 2B**). Several vascular stents (peripheral self-expanding stent system, 6 × 8 mm, 6 × 10 mm) were implanted from the distal end of the bypass vessel in Group C patients under ultrasonography or angiography guidance **(Figure 2C**). These stents covered the LPV- UV-vascular anastomotic stomas and bypass vessels (**Figure 2D**). The patient in Group B did not have a stent implantation procedure. The distal anastomosis of bypass in Group B and C was the same as in Group A. After the vascular anastomosis was completed, the bloodstream was opened to check for bleeding and whether vascular filling was good (**Figure 2E**).

The patient's blood flow was checked by ultrasonography after surgery [11] (**Figure 3 A**). Pre- and postoperative images using enhanced CT revealed that the bypass vessels were unobstructed, the lumen diameter was appropriate, intrahepatic portal vein blood flow was filled, and the pre-operative varicose right gastroepiploic vein diameter became smaller (**Figure 3B)**.

Anticoagulant therapy

All patients received anticoagulant therapy after surgery. The regimen was to intravenously infuse heparin within 2-3 days of surgery to maintain the activated partial thromboplastin time (APTT) between 50 and 70 s, and then switch to a preventive dose of low molecular weight heparin. After discharge, the patient took rivaroxaban orally 20 mg or aspirin 100 mg once a day. Anticoagulation therapy was generally recommended for 3-6 months and patients with stent implantation and risk of thrombosis should be given anticoagulation therapy for > 1 year or even for their lifetimes.

Statistical Analysis

Pre- and postoperative data including bypass vascular flow, the diameter of the narrowest part of the blood vessel, opening times and the incidence of vascular occlusion were collected and analyzed using SPSS ver. 20 (IBM Corporation, Armonk, NY, US). Measurement data for skewed distributions are reported as medians (range). The measurement data for normal distribution are presented as the mean ± SD and paired data analyzed using a paired *t*-test. $P < 0.05$ was considered to be a statistically significant difference.

Results

Basic characteristics of patients

Of the 13 patients, 9 were male and 4 were female, with a mean age of 36 years (range: 11-62). All patients had a history of gastrointestinal bleeding before surgery, which was hematemesis or melena. Six patients underwent gastroscopy to confirm the presence of esophageal gastric varices or portal hypertensive gastropathy, and one patient considered to have variceal bleeding at the site of a biliary-enteric anastomosis. Pre-operative enhanced CT and B-ultrasonography (BUS) confirmed the PVCT, with an unobstructed intrahepatic PV and SMV trunk without lesion in the hepatic outflow tract. Nine patients had a history of abdominal diseases that might induce PVCT, including biliary-enteric anastomotic stenosis (1 case), pyleophlebitis secondary to appendicitis (1 case), liver trauma surgery (1 case), liver transplantation (2 cases), *ex situ* hepatectomy (1 case), bowel obstruction (1 case), pancreatitis (1 case) and previous MRB surgery (1 case). Three patients had a risk of thrombosis with decreased protein C activity or lower antithrombin III levels. Pre-operative or intra-operative biopsy confirmed that there was no liver cirrhosis or hepatic venous disease. All patients were confirmed to have MRB surgical indications and were eligible for surgery. Only 4 patients in Group A used autologous right internal jugular veins, and the remaining 9 patients used allogeneic blood vessels. In Group A, 1 patient simultaneously underwent biliary-enteric anastomosis reconstruction and cholangiolithotomy and 1 patient simultaneously underwent cholecystostomy and splenic artery ligation. Of the 13 patients, 5 patients received end-to-end anastomosis of the bypass vessel with the confluence of SMV and SpV, and 8 patients received anastomosis of the bypass vessel with the SMV or SpV trunk.

Postoperative patency and outcomes of interventional or surgical treatments

All patients obtained a satisfactory decompression effect after bypass surgery, and the intra-operative SMV pressure decreased from 36.77 ± 4.48 cmH_2O (29-44 cmH_2O) to 24 ± 5.08 cmH_2O (16-31 cmH_2O) ($P < 0.01$). The MRB opening time for patients using autologous blood vessels was 0-59 months (median 35 months), and the MRB opening time for patients used allogeneic blood vessels was 0-49 months (median 6 months) ($P > 0.05$).

Group A: The mean blood flow velocity of patients in Group A was 25-115 cm/s (median 75 cm/s) at 1 month after MRB, 0-161 cm/s (median 87.5cm/s) 3 months after MRB and 0-180 cm/s (median 73 cm/s) 1 year after MRB, and the opening time of bypass was 0-59 months (median 16 months). In Group A, 5 of 8 patients developed postoperative MRB occlusions, from which 4 underwent surgery or interventional treatments for the thrombus or stenosis of the bypass vessels at 0-6 months (median 3 months) after MRB surgery.

By the end of the follow-up, 3 patients still had MRB occlusion (1 patient developed occlusion at 26 months after MRB and was not treated subsequently; 1 patient occluded again after intervention and recanalization, without treatment subsequently; 1 patient was found to be unable to be recanalized during interventional treatment, and no other treatment was performed.). The diameter of the bypass vessels after MRB surgery was 2-6 mm (median 3.3 mm), among which 5 patients had an MRB occlusion with < 4 mm vessel diameter, but no embolism occurred in patients with a bypass vessel diameter ≥ 4.

Vessel diameters in 2 patients with vascular occlusions were 2 and 2.5 mm, while the re-examined diameters were 5 mm after interventional therapy with recanalization and stent implantation. The bypass vessel remained unobstructed from the time of stent implantation to the end of follow-up. One patient was recanalized only by surgical thrombus extraction and reshaping the diameter of the vascular anastomotic stoma, without stent implantation, and occlusion occurred 15 months after the 2 operations.

Group B: The patient comprising Group B needed thrombectomies and stent implantation during a second surgery 2 days after mMRB because of bypass thrombosis and UV stenosis. The MRB remained unobstructed for 26 months from the time of stent implantation to the end of follow-up, with a vessel diameter of 5 mm and a blood flow rate of 42 cm/s (1 year after MRB).

Group C: A total of 9 stents were implanted in 4 patients, of which 3 were implanted in 1 patient and 2 implanted in each of the remaining 3 patients. All patients successfully received recanalization of the UV and resistance could be detected at the junction of the UV and the sagittal part of PV, which is a narrow ring. All patients were able to successfully receive an implant stent in the LPV-UV through the distal end of the bypass vessel.

All bypass vessels remained open in all patients in Group C with satisfactory blood flow rates (45-100 cm/s, median 76.5 cm/s) 1 month after MRB, 28-80 cm/s (median 59 cm/s) 3 months after MRB and 65-83 cm/s (median 66 cm/s) 1 year after MRB up to the endpoint (12-26 months, median 18 months). The diameter of the bypass vessels after MRB surgery was 5.5-6.5 mm (median 6 mm).

The rate of bypass closure in Group A *vs* Group C at 1 month, 3 months and 1 year after MRB surgery was 25% *vs* 0%, 25% *vs* 0% and 50% *vs* 0%, respectively.

Adverse Events

No non-bypass vessel related Clavien-Dindo grade III or higher complications occurred. Patients in Group A, who underwent reconstruction of the biliary-enteric anastomosis, suffered from bile leakage and abdominal infection after surgery and were treated with laparotomy again. In Group C, 1 patient developed a jejunal fistula after surgery and was cured by re-operation, which was considered to be related to an intra-operative thermal injury and no complications occurred in the remaining 3 patients.

Discussion

Anatomical basis of surgical feasibility and stent implantation

After the left UV enters the liver from the umbilicus along the margin of the falciform ligament during the fetal period, it branches into two: one vein that extends directly into the Arantius tube and is connected to the inferior vena cava and the other is connected to the LPV. After birth, the pressure of the UV decreases and the vascular wall shrinks and gradually closes. There have been reports of MRB surgery with UV recanalization, mainly for underage patients [12, 13], but without the use of intra-operative stents.

The present study suggested that this type of end-to-end anastomosis was more convenient and it was easier to achieve intravascular therapy, allowing a large-caliber anastomosis and a good portal blood flow volume. It should be pointed out that a high-pressure sodium heparin perfusion for the recanalized UV helped to maintain this access patency and thus the intrahepatic PV circulation. In clinical practice, we found that there was a “septum structure” in the transition from adult UV to PV, which is a natural narrowing ring. The patency of this narrow lumen must be ensured by intra-operative stenting; otherwise vascular occlusion and thrombosis (Group B patients) will certainly occur, which may also be the main difference between adult and pediatric patients. After stent implantation, the head-end of the stent should ideally be positioned at the confluence of the left and right PV, covering the entire left PV-UV-bypass vessel. A non-covered stent was selected during the operation so that blood could flow into the P2, P3 and P4 branches of the PV sagittal part through the side hole of the stent, ensuring a good blood supply to the left liver.

Surgical advantages of umbilical vein recanalization

In classical MRB, a portion of the liver (from both segments III and IV) around the umbilical scissure has to be resected to create a route for the bypass and to avoid compression by the liver edges. Before anastomosis on the Rex recessus, a Satinsky clamp was positioned behind the branches for segments II, II and IV and a vertical incision made on the ventral aspect of the Rex recessus at the margin with the umbilical remnant. Our surgical approach simplifies the anatomy of Rex recessus, avoiding liver resection and left hepatic surface adhesiolysis, especially for patients with severe abdominal adhesions, left liver hyperplasia or a Rex recessus deeply buried in the liver (Figure 4A). In cases where the UV was not patent, the sagittal part of the LPV can be used for a side-to-end anastomosis, according to the classical MRB procedure.

The necessity for a primary stent implantation

There are many reasons leading to thrombosis after MRB surgery, including the diameter of blood vessels, whether there is a hypercoagulability state, the pressure gradient difference between the two sides of the bypass vessels and the condition of the bypass vessels. Previous reports have suggested that the risk of embolism in the autologous vasculature is less than in allogeneic and artificial blood vessels. Our results suggested that the opening time of allogeneic blood vessels in Group A patients was shorter than for autologous blood vessels, a finding consistent with previously published literature. However, this comparison did not reach statistical significance, we believe mainly due to the small sample size and to brief follow-up times. In addition to being squeezed by surrounding tissues, surgery may also stimulate inflammation and fibrous tissue hyperplasia around the bypass vessels, or immune response to allogeneic blood vessels, resulting in postoperative bypass vascular stenosis and anastomotic stenosis, thereby producing vascular occlusion. The main aim of the primary stent implantation approach is to solve the problem of thrombus formation or vascular occlusion in bypass vessels caused by vascular diameter stenosis. For example, in Group A patients, the anastomotic diameter at Rex was both confirmed to be greater than 5 mm during surgery, and 5 of them narrowed to less than 4 mm in diameter after surgery, resulting in occlusion. Two of the patients underwent interventional stent implantation after vascular occlusion, which expanded the blood vessel diameter to more than 5 mm, and no embolism occurred again (**Figure 4B**). Therefore, it is fully explained that the stent implantation helps to ensure the patency of blood vessels and avoid the existence of narrow regions.

Intra-operative primary stent implantation can be achieved under the guidance of ultrasonography or angiography, which permits superior hand control and vascular access under direct vision and also reduces the risk of postoperative secondary interventional therapy as a result of liver or spleen puncture. Our mode of operation is similar to the p4 stump approach for intra-operative portal vein stenting in pediatric living donor liver transplantation [14]. Ultrasonography should be performed every day within 2 weeks of surgery to make sure that blood flow is fluent. In addition, patients undergoing stent implantation or patients at risk of thrombosis (including those that have had a previous thrombosis or a flow rate in bypass vessels of < 20 cm/s) may require lifetime anticoagulant therapy to prevent stent thrombosis. Our anticoagulation regimen is to infuse heparin within 3 days of surgery, maintain APTT between 50 s and 70 s, and to switch to a therapeutic dose of low molecular weight heparin after 3 days, followed by a change to oral rivaroxaban 20 mg qd or aspirin 100 mg qd about 2 weeks after surgery. Oral warfarin could also be used to maintain INR at 2-3, but at present there is no uniform anticoagulation standard. The small sample size of our study may lead to bias, therefore, a long-term follow-up with a larger cohort of patients is still needed to determine whether this surgical approach helps maintain satisfactory long-term blood flow in bypass vessels.

Conclusion

In conclusions, UV can be used as a conduit of MRB in adult patients and an intraoperative stent must be implanted. Compared with the traditional MRB surgery, this approach is relatively simple and it ensures satisfactory bloodstream access, which will reduce the risk of intravascular thrombosis and bypass vessel occlusion after surgery.

Abbreviations

APTT: activated partial thromboplastin time, BUS: B-ultrasonography, LPV: left portal vein, mMRB: modified MRB, MRB: Meso-Rex bypass, PVCT: Portal vein cavernous transformation, SMV: superior mesenteric vein, SpV: splenic vein, PV: portal vein, UV: umbilical vein

Declarations

Ethics approval and consent to participate

The ethics committee of Beijing Tsinghua Changgung Hospital approved the study and written informed consent was obtained from all participants.

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests

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Authors' contributions

Conception and design: RT, LY, GW, AL, YZ and QL

Collection and assembly of data: RT, GW, AL, YZ and YL

Data analysis and interpretation: RT, LY, IL and XY

Manuscript writing: All authors

Final approval of manuscript: All authors

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Figures

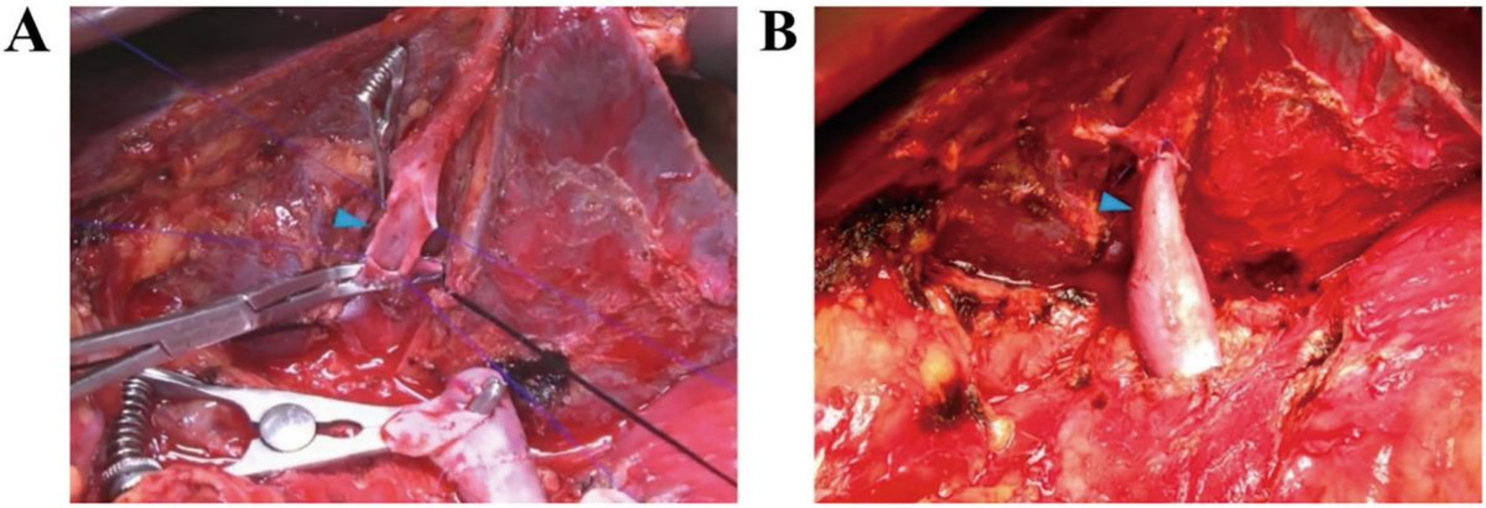

Figure 1

Traditional MRB surgery for treatment of the portal vein sagittal section. The blue arrows show the vascular anastomotic stoma of the sagittal section before A) and B) after anastomosis.

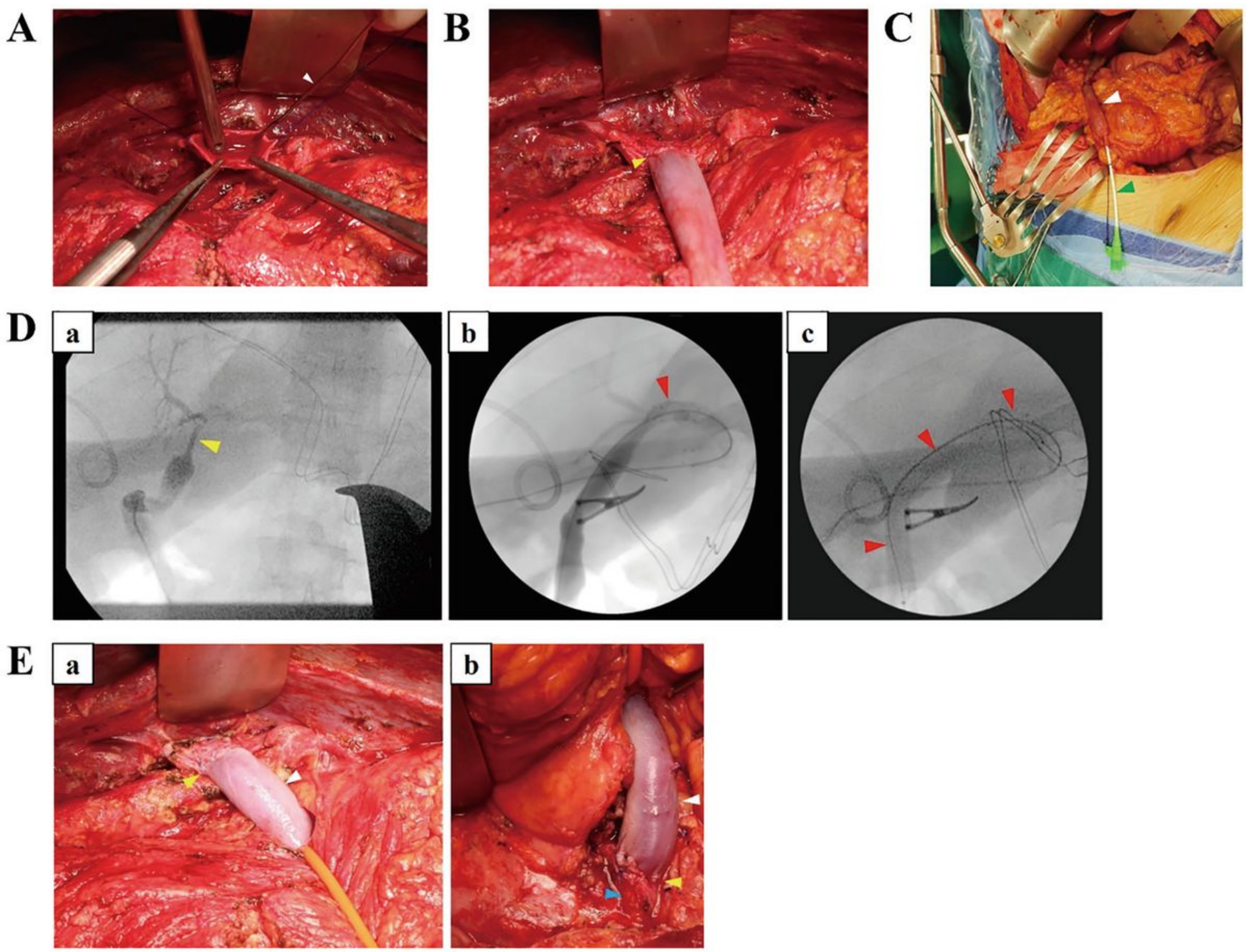

Figure 2

Intra-operational images of modified mMRB surgery. A) UV recanalization. The white arrow shows the vascular dilator. B) After the UV was recanalized, the end-to-end anastomosis was performed with the bypass vessel. The yellow arrow indicates the anastomotic stoma. C) Ultrasonography or radiography guided stent implantation of the bypass vessel into the LPV. The white arrow indicates the bypass vessel and the green arrow indicates the angiographic catheter. D) Intraoperative angiography revealed that the UV and LPV were narrowed (yellow arrow in a) and b) improvement of the blood vessel diameter after stent implantations. c) The successively implanted stent covers the LPV-UV-anastomotic stoma-bypass vessel to ensure the patency of the vascular lumen (red arrows indicate the vascular stent). E) Intraoperative images of a) the upper and b) lower anastomotic stoma after the mMRB surgery was completed (the yellow arrows indicate the vascular anastomotic stoma; the white arrows indicate the bypass vessel in which the stent is visible; the blue arrow indicates the SMV).

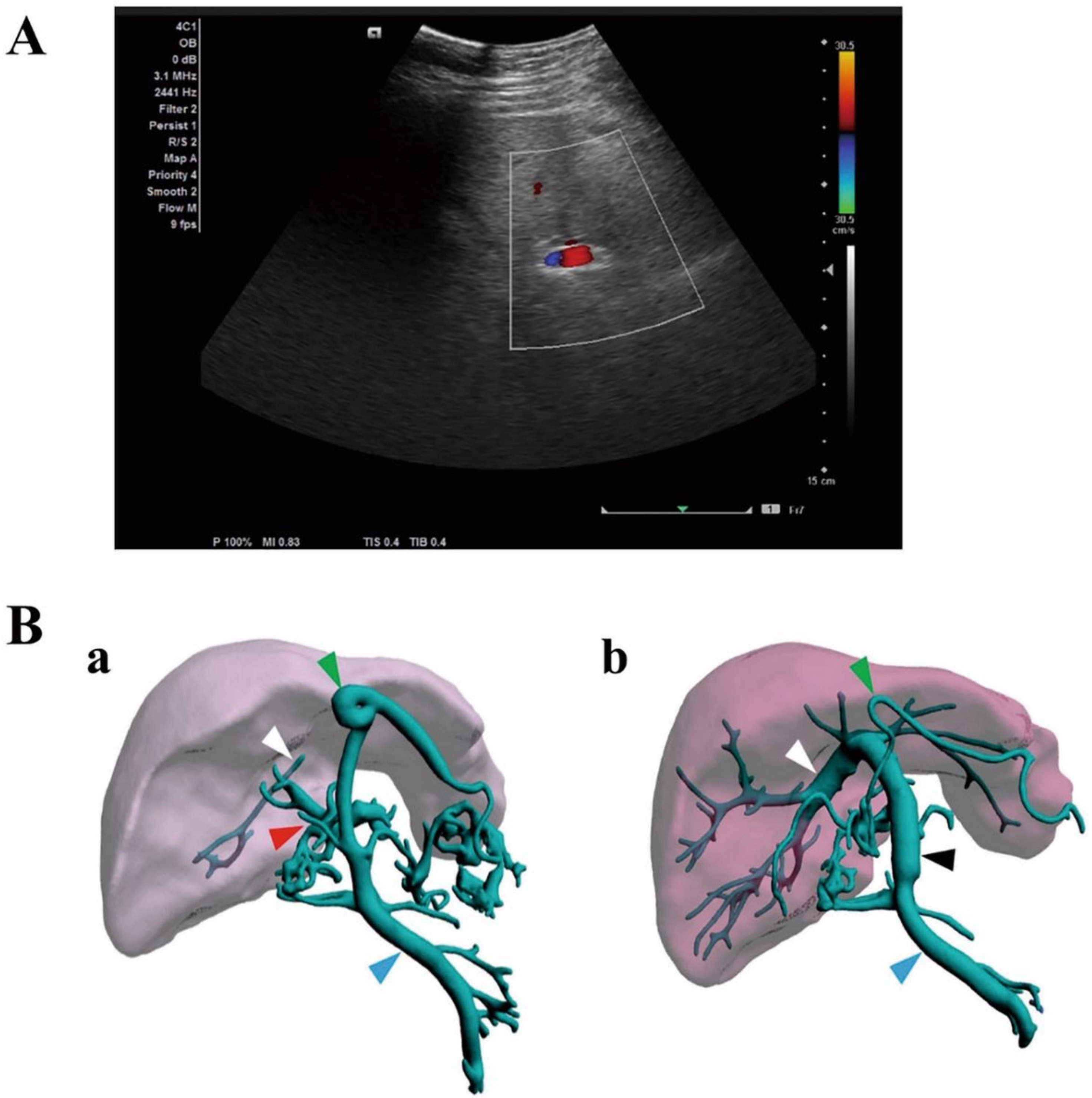

Figure 3

Post interventional ultrasound and 3D images of livers in Group C before and after surgery. A) Ultrasonography showing the vascular stent and blood flow in the stent. B) Pre-operative a) and postoperative b) Three-dimensional reconstruction of patients in Group C (the white arrows indicate the LPV, the red arrow indicate the PVCT in the hepatic hilar region, the blue arrows indicate SMV, the black arrow indicates the bypass vessel and its internal stent, and the green arrows indicate the right gastroepiploic vein).

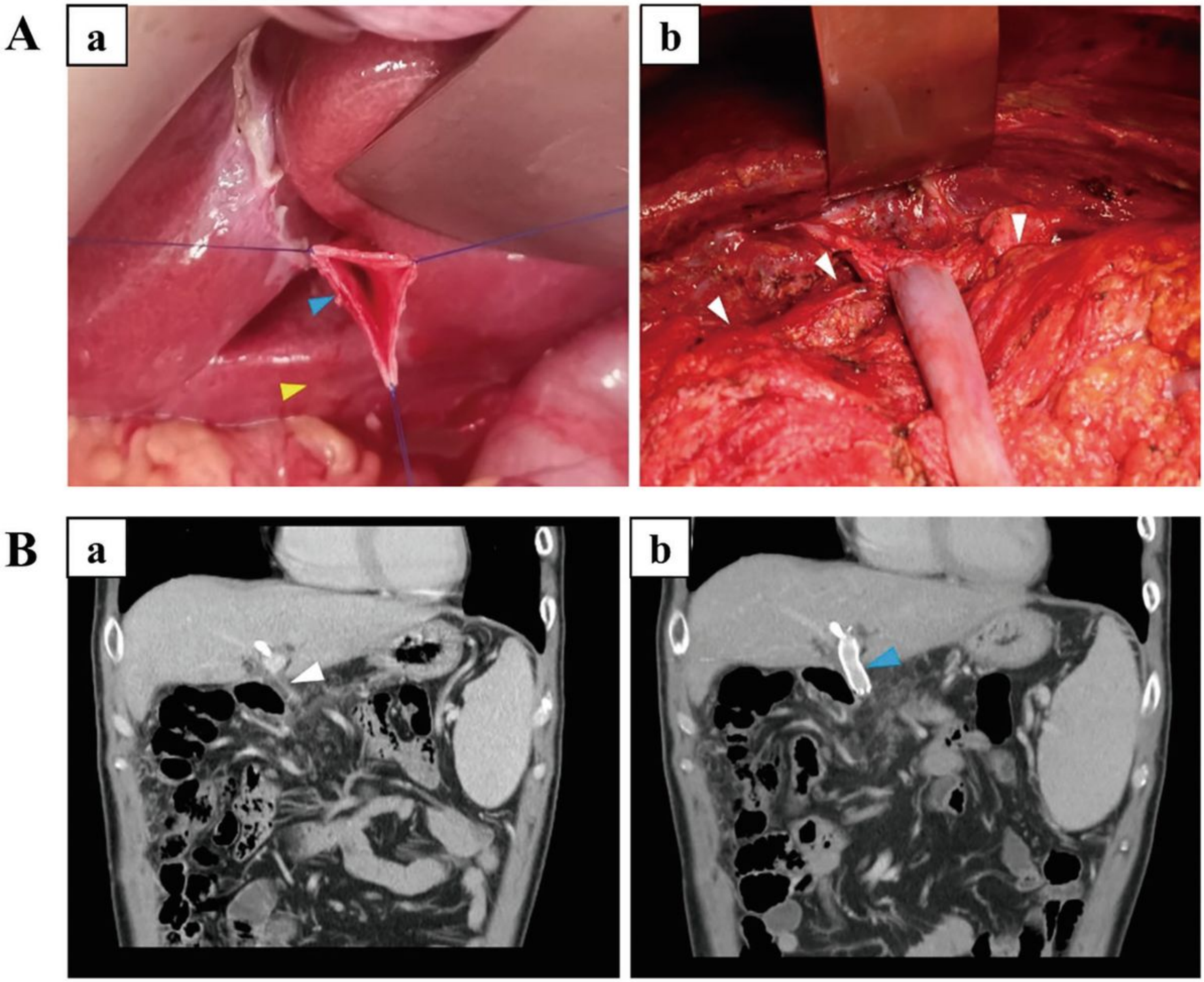

Figure 4

Images of UV recanalization in mMRB surgery and stenosis after traditional MRB surgery. A) The UV recanalization avoids resection of hepatic bridge and separation of excessive adhesion. a) The yellow arrow indicates the hepatic bridge covering the LPV, the blue arrow indicates the recanalized UV, and b) The white arrow indicates the adhesion of the left hepatic surface. B) a) Stenosis of anastomotic stoma and bypass vessels after traditional MRB surgery (the white arrow indicates a narrow bypass vessel) and b) the improvement of vessel diameter after postoperative interventional stent implantation (the blue arrow indicates a bypass vessel that expanded after stent implantation).