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ORIGINAL ARTICLE

Saphenous vein conduits for hepatic arterial reconstruction in living donor liver transplantation

Abu Bakar Hafeez Bhatti[1] · Faisal Saud Dar[1] · Ammal Imran Qureshi[1] · Siraj Haider[1] · Nasir Ayub Khan[2]

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Abstract

Purpose Occasionally, a recipient's native hepatic arteries are not suitable for reconstruction in living donor liver transplantation (LDLT). The use of the great saphenous vein (GSV) conduits in such patients is seldom practiced since arterial conduits from deceased donors are available. Here, we share our experience with a significantly large group of LDLT recipients who underwent arterial reconstruction with GSV conduits.

Methods We reviewed patients who underwent LDLT between 2012 and 2017. Patients who had arterial reconstruction using native hepatic arteries (group 1)($n = 452$) were compared with those who had GSV interposition conduits for reconstruction (group 2)($n = 21$). We compared hepatic artery thrombosis (HAT) rate, allograft dysfunction, morbidity, mortality, and actuarial 5-year survival in the two groups.

Results HAT was seen in 0/452 (0%) versus 1/21(4.7%) patients ($P = 0.04$). Allograft dysfunction was seen in 89/423 (21%) versus 6/19(31.5%) ($P = 0.2$) patients. Overall mortality was 81/452 (17.9%) versus 8/21(38%) ($P = 0.02$). Death after a biliary complication was seen in 24/452 (5.3%) versus 4/21 (19%) patients ($P = 0.02$). Actuarial 1- and 5-year overall survival was 85% versus 67% and 79% versus 58% ($P = 0.008$).

Conclusion GSV conduits are a suboptimal alternative for establishing hepatic arterial inflow in LDLT, but remain valuable in ominous situations.

Keywords Graft dysfunction · Hepatic artery thrombosis · Aorto hepatic conduit · Mortality · Survival

Introduction

In living donor liver transplantation (LDLT), vascular complications are associated with significant morbidity and mortality [1]. Hepatic artery thrombosis (HAT) remains one of the most serious complications after LDLT. It occurs in 4–25% of patients and leads to early graft loss due to septic infarction of the liver [2]. Considering the scarcity of donors in LDLT, retransplantation is seldom possible and leads to mortality in many of these patients [3]. Occasionally, an intraoperative event such as intimal dissection during recipient hepatectomy renders native recipient hepatic artery unsuitable for reconstruction. Scarring from previous surgery or poor caliber from repeated transarterial chemoembolization (TACE) procedures also increases this risk [4]. Arterial reconstruction in such a situation can be performed with extra-anatomic conduits. Most frequently used conduits include right gastric artery (RGA), right gastroepiploic artery (RGEA), left gastric artery (LGA), and splenic arteries (SA) [5]. Due to mismatch in vascular diameter between graft hepatic artery and extra-anatomic conduit or insufficient blood flow to sustain high graft to recipient weight ratio (GRWR), they are not always a suitable option [3]. Aortohepatic conduits from either infrarenal or supraceliac location with donor iliac arteries as interposition grafts might represent a suitable alternative for establishing blood flow [5, 6]. In pure LDLT centers, donor iliac arteries are not available and other options have to be considered. In such scenarios, great saphenous vein (GSV) interposition conduits might be a viable alternative. The GSV interposition conduits have not been compared with standard arterial reconstruction in

✉ Abu Bakar Hafeez Bhatti
abubakar.hafeez@yahoo.com

[1] Department of HPB Surgery and Liver Transplantation, Shifa International Hospital, Sector H-8/4 Pitras Bukhari Road, Islamabad, Pakistan

[2] Department of Anesthesiology, Shifa International Hospital, Sector H-8/4 Pitras Bukhari Road, Islamabad, Pakistan

LDLT. The current study reports the largest experience with the use of GSV conduits in LDLT.

The objective of this study was to compare outcomes for patients who underwent hepatic arterial reconstruction using native hepatic arteries with patients who had GSV interposition conduits for arterial reconstruction.

Material and methods

We reviewed a prospectively maintained database of adult patients who underwent LDLT at Shifa international hospital Islamabad between April 2012 and September 2017. After exclusion of pediatric transplants and transplants performed for acute liver failure, 473 patients were included in this study.

Details of donor/recipient selection and evaluation process have been detailed elsewhere [7, 8]. In general, donors were blood group compatible, related (legally or blood) and ≤ 50 years of age. They had comprehensive preoperative laboratory workup and imaging including dynamic CT scan of the liver with volumetry and MRCP for delineation of biliary anatomy and assessment of suitability for donation.

During recipient hepatectomy, a high hilar dissection was performed to preserve the length of hepatic arteries and a temporary portocaval shunt was performed in majority of patients. The left and right hepatic arteries were skeletonized up to proper hepatic artery (PHA) and dissected off the bile duct. At this stage, if the recipient's native hepatic arteries were deemed unsuitable for reconstruction; PHA common hepatic artery (CHA) and SA were assessed for reconstruction. If the dissection had extended to these arteries or if there was inadequate length for arterial reconstruction, an 18–20 cm segment of the left great saphenous vein (GSV) was procured (Fig. 1). If used as aortohepatic conduit, we preferred placing the vein between infra renal aorta and graft's hepatic artery. The conduit was brought up into the lesser sac in retrocolic ante pancreatic fashion (Fig. 2). The aorta was partially clamped during the aorto-saphenous anastomosis which was performed with interrupted Prolene 6/0 sutures. After completion of this anastomosis, clamps were removed from the aorta and a bull dog clamp was applied on the saphenous vein during distal anastomosis with graft's hepatic artery. Orientation of the GSV conduit was checked after completion of anastomosis (Fig. 3). All patients had intraoperative doppler ultrasonography after arterial reconstruction to assess adequacy of arterial and portal inflow and hepatic venous outflow. A liver doppler was performed daily until postoperative day 5. If doppler findings were worrisome, a dynamic CT scan of the liver was performed to confirm doppler findings. Daily baseline labs "liver function tests," "magnesium," "phosphate," "albumin," and prothrombin time (PT/INR) were performed until discharge. Patients with conduits were placed on intravenous heparin with a target activated partial thromboplastin time (APTT) between 60 and 80 s. All other patients received low molecular weight heparin (LMWH) unless a contraindication existed.

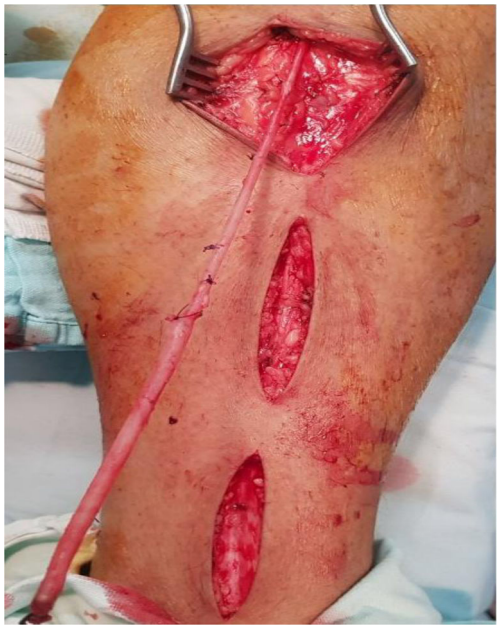

Fig. 1 Great saphenous vein (GSV) conduit procurement

For the purpose of this study, patients were divided into two groups. Group 1 included patients who underwent arterial reconstruction using recipient's native hepatic artery ($N = 452$) while group 2 patients had arterial reconstruction with GSV conduit ($N = 21$). The two groups were compared for demographics, and graft and operative variables. Graft variables

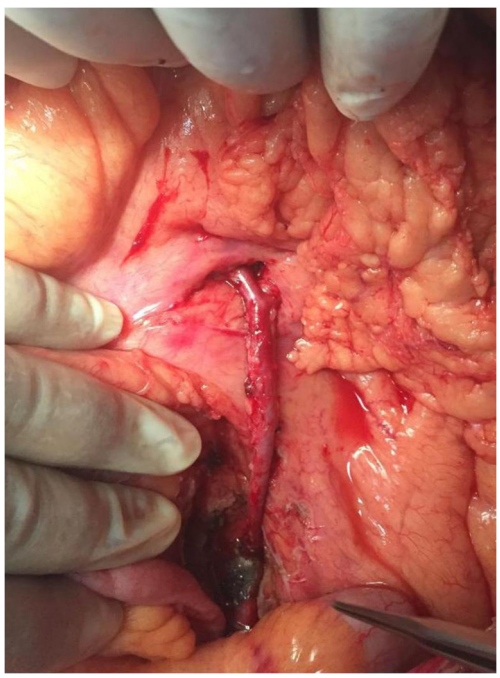

Fig. 2 Aorto-saphenous anastomosis of GSV conduit placed in retro colic fashion

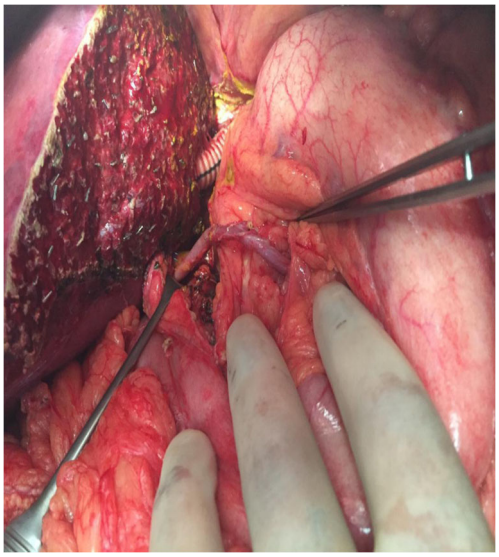

Fig. 3 Alignment of GSV conduit after anastomosis between RHA and GSV conduit

included graft type, graft to recipient weight ratio (GRWR), and liver attenuation index (LAI). Among operative variables, cold ischemia time (CIT) and warm ischemia time (WIT), blood loss, operative time, and number of biliary and hepatic venous anastomoses were compared. The outcome was assessed based on the rate of hepatic artery thrombosis (HAT), early allograft dysfunction (EAD) [9], morbidity, and mortality. Clavien–Dindo grading was used to classify severity of complications and grade 2 and above complications were compared between the two groups [10]. In addition, we compared overall survival in the two groups. For interval variables, *t* test or Mann Whitney *U* test was used as appropriate. For categorical variables, Fisher's exact test and chi square test were used. Survival was calculated using Kaplan Meier curves and log-rank test was used to determine significance. A P value < 0.05 was considered statistically significant. Overall survival was calculated by subtracting date of last follow up/death from date of surgery. The study was approved by the hospital ethics committee.

Results

Patient characteristics

Median follow up for the study cohort was 18 (0–67.4) months. Mean age was 47.3 ± 10.4 years. Mean body mass index (BMI) was 24.9 ± 4.8 kg/m^2. Median model for end-stage liver disease (MELD) score was 21(6–40). Male to female ratio was 4.2:1. Most common underlying etiology was chronic hepatitis C virus (HCV) infection in 316 (66.8%) patients. Out of total, 121 (25.5%) patients had underlying hepatocellular carcinoma (HCC). Out of these patients, 32 (26.4%) underwent transarterial chemoembolization (TACE) preoperatively.

Median age for the two groups was 48 (18–73) and 48 (30–60) years ($P = 0.6$). Median MELD score was 21(6–40) and 24 (10–32)($P = 0.8$). No significant difference was seen for gender, etiology, MELD groups, HCC, and preoperative TACE in the two groups (Table 1). The technical details of the GSV conduits are shown in Table 2. Intimal dissection during recipient hepatectomy was the most common indication for its use and infrarenal aorta was the preferred site. In one patient, a polytetrafluoroethylene (PTFE) graft was used as the initial conduit of choice but immediate graft thrombosis was noted and so it was taken down and replaced with a GSV conduit.

Operative variables

Median CIT in the standard and GSV group was 38 (5–215) and 48 (15–160) minutes ($P = 0.3$). Median WIT was 38 (13–93) and 39 (25–60) minutes ($P = 0.9$). Median blood loss in the two groups was 1700 (19–30,000) and 2000 (600–11,000) milliliters ($P = 0.2$). Median duration of surgery was 9.2 (6–20) and 10.3(7–20) hours ($P = 0.1$). A graft with GRWR > 0.8 was used in 386/452(85.3%) in the standard and 21/21 (100%)($P = 0.04$) patients in the GSV group (Table 3).

Outcomes

Median ICU stay was 4 (0–82) and 4.5 (1–37) days ($P = 0.9$), while hospital stay was 17 (2–129) and 19 (2–46) days ($P = 0.6$) in the standard and GSV groups respectively. There was 100% (452/452) graft patency in the group with native hepatic arterial reconstruction and (20/21) 95.3% in the GSV conduit group ($P = 0.04$) (Table 4). One patient with HAT in the GSV group underwent revascularization with a second GSV conduit from the opposite leg and did well postoperatively. No significant difference in morbidity was noted between the two groups. However, postoperative bleeding secondary to coagulopathy was seen more frequently in the GSV group, i.e., 2.8% versus 14.2% ($P = 0.02$). Table 5 demonstrates the cause of death in two groups. There was a significant difference in mortality between the two groups, i.e., (81/452)17.9% versus (8/21)38% ($P = 0.02$). Biliary complications led to significantly more deaths in the GSV group, i.e., 5.2% and 19% ($P = 0.02$). A similar trend was observed for postoperative bleeding in GSV group, i.e., (1.5% versus 9.5%) ($P = 0.05$). Further analysis of the GSV group showed that cause of death was a biliary complication in 4/8 (50%) patients, postoperative bleeding in 2/8 (25%) patients while septicemia and myocardial infarction in one patient each. There was no significant difference in the biliary complication rate with single versus two biliary anastomoses, i.e., 3/7 (42.8%) versus 5/14 (35.7%) ($P = 1$). Sepsis was more frequently seen in the group with biliary complications 4/8 (50%) versus 1/13 (7.7%)($P = 0.04$). There was high mortality in patients with sepsis 4/5 (80%) versus 4/16 (25%)($P = 0.04$). The actuarial 1- and 5-

Table 1 Patient characteristics

		Standard group $N = 452$		GSV conduit group $N = 21$		
		Number	Percent	Number	Percent	*P* value
Gender	Male	368	81.4	15	71.4	0.2
	Female	84	18.6	6	28.6	
Etiology	Hepatitis C	302	66.8	14	66.6	1
	Hepatitis B	63	13.9	3	14.2	
	Others	87	86.1	4	85.8	
MELD group	< 10	18	3.9	1	4.7	0.9
	11–20	194	42.9	9	42.8	
	21–30	179	39.6	9	42.8	
	> 30	61	13.6	2	9.7	
Hepatocellular carcinoma	Yes	116	25.7	5	23.8	0.8
Pre op trans arterial chemoembolization	Yes	31	6.8	1	4.7	0.5

year overall survival was 85% versus 67% and 79% versus 58% ($P = 0.008$) as shown in Fig. 4.

Discussion

This is the first report comparing outcomes of GSV interpositional conduits for arterial reconstruction in LDLT with standard arterial reconstruction using recipient native hepatic arteries. The GSV conduits showed excellent patency rates but were associated with high patient mortality. There was a high rate of failure to rescue (FTR) in patients who had a biliary complication in the GSV group. We have previously shown that FTR rates are lower in the presence of biliary complications [11]. This is contrary to our current findings where biliary complications in GSV group were less likely to be rescued. Biliary complications were almost twice as common in patients with the GSV conduits than a previously reported rate from our center [7]. The use of aortohepatic conduits has been linked with increased risk of ischemic cholangiopathy and might explain the inability to rescue these patients after a biliary complication leading to sepsis and death [12, 13]. Prolonged interruption of hepatic arterial inflow while attempting to fashion a GSV conduit might have a role since the use of aortohepatic conduits increases risk of ischemic cholangiopathy. Early identification of intimal dissection before the graft is extracted from the donor and setting up the GSV conduit before graft implantation is begun can reduce arterial inflow interruption time. Sepsis was seen more frequently in patients with biliary complications and was associated with high mortality.

Table 2 Technical details of great saphenous vein conduits

		Number $N = 21$	Percent
Cause	Intimal dissection	18	85.7
	Inadequate blood flow	2	9.5
	Failed anastomosis	1	4.8
Origin	Infra renal aorta	16	76.2
	Supra celiac aorta	3	14.2
	Left gastric artery	1	4.8
	Common hepatic artery	1	4.8
Conduit of choice	Primary	20	95.2
	Secondary	1	4.8

Postoperative bleeding mandating a laparotomy led to mortality in 25% patients with GSV conduits. With the expected increase in risk of HAT in patients with GSV conduits, intravenous heparin was used exclusively to prolong APTT. This coupled with widespread areas of dissection to determine suitability of other arteries or aorta for reconstruction increased the risk of uncontrolled postoperative bleeding. In all patients explored for bleeding, no obvious bleeder was identified and there was diffuse ooze from raw surfaces.

Despite its technical issues and surgical cumbersomeness, GSV conduits showed excellent patency in our patients. Only one patient required removal of GSV conduit and interposition with a new GSV conduit was performed. Extra-anatomic conduits including SA, LGA, RGA, and RGE artery have been used in patients with intimal dissection and size mismatch with good results [4, 14]. In our experience, in presence of hepatic artery dissection, the integrity of these arteries is often questionable. In the majority of cases, dissection extends proximally to involve celiac axis and these arteries are not suitable for reconstruction. This is different from the scenario where extra-anatomic conduits are used for HAT where SA, LGA, and RGE are often spared. In LDLT, partial grafts have short hepatic arteries and interpositional conduits are essential to establish arterial inflow from the aorta or other suitable

Table 3 Operative details

		Standard group $N=452$		GSV group $N=21$		P value
Graft type	Right	439	97.1	21	100	0.5
	Left	23	2.9	0	–	
Middle hepatic vein used	No	309	68.3	11	52.4	0.1
	Partial	110	24.3	9	42.8	
	Subtotal	33	7.4	1	4.8	
Biliary anastomoses	One	330	73	14	66.7	0.5
	Two	115	25.4	7	33.3	
	Three	3	0.7	0	–	
	Hepaticojejunostomy	4	0.9	0	–	
Graft to recipient weight ratio	> 0.8	386	85.3	21	100	0.04*
	< 0.8	65	14.7	0	–	
Liver attenuation index	< 5	39	8.6	5	23.8	0.01
	> 5	413	91.4	16	76.2	
Portal flow modulation	Yes	37	8.2	2	9.6	0.5
	No	415	91.8	19	90.4	
Outflow veins	1	122	27	5	23.8	0.9
	2	272	60.1	14	66.6	
	3	52	11.5	2	9.6	
	4	4	1.4	0	–	

arteries. Donor iliac arteries or cryopreserved grafts are a suitable alternative if available.

In deceased donor liver transplantation (DDLT), comparable long-term outcomes with infra renal aortohepatic conduits using donor iliac arteries have been demonstrated [14]. However, hepatic artery and graft thrombosis remain a major problem with use of conduits [15–18]. Autologous saphenous vein grafts have occasionally been used to manage hepatic artery pseudoaneurysms [19–22]. It is only recently that the use of supraceliac aortohepatic conduits using saphenous vein grafts in LDLT has been reported in 11 patients. The authors demonstrated excellent patency of GSV grafts and argued against the use of infrarenal aortohepatic conduits owing to less tissue dissection, reduced bleeding, and better alignment

Table 4 Comparison of outcomes between the two groups

	Standard group $N=452$		GSV group $N=21$		P value
	Number	Percent	Number	Percent	
Hepatic artery thrombosis	0	–	1	4.7	0.04*
Allograft dysfunction	89/423*	21	6/19**	31.5	0.3
Total patients experiencing morbidity	342	77.8	17	80	0.4
Biliary complications	122	26.9	8	38	0.2
Sepsis	107	23.6	5	23.8	0.9
Renal insufficiency	66	14.6	4	19	0.3
Intraabdominal collection	68	15	4	19	0.4
Postoperative bleeding	13	2.8	3	14.2	0.02*
Pleural effusions	108	23.8	7	33.3	0.3
Acute cellular rejection	67	14.8	4	19	0.5
Chronic rejection	21	4.6	1	4.7	1
Psychosis	71	15.7	1	4.7	0.2
Fits	26	5.7	4	19	0.03*
Mortality	81	17.9	8	38	0.02*

*29 patients in group 1 and 2 in group 2 expired within 7 days and so allograft dysfunction could not be assessed

Table 5 Cause of death in the two groups

		Standard group $N = 452$		GSV group $N = 21$		
	Total	Number	Percent	Number	Percent	*P* Value
Biliary complications	28	24	5.3	4	19	0.02*
Septicemia	22	21	4.6	1	4.7	0.6
Bleeding	9	7	1.5	2	9.5	0.05*
Myocardial infarction	4	3	0.6	1	4.7	0.1
Graft dysfunction	3	3	0.6	0	–	1
Renal failure	3	3	0.6	0	–	1
Others	24	24	5.3	0	–	0.6

of the interpositional conduit in the supra celiac position. The authors, however, did not comment on short-term and long-term mortality rates in these patients and its comparison, with the standard group was not made. Three out of 11 patients had conduit placement for HAT where the first arterial reconstruction was performed with the native artery. We remain unaware of the MELD scores in these patients. It can be assumed that these were not very sick patients since at least five out of 11 had HCC. To summarize, the study by Li and colleagues does not offer much information regarding included patients and their long-term follow-up. It does however establish GSV conduits as an important resource for arterial supply to the graft [3]. To the contrary, all patients in the current study had an intraoperative event. In the early days of evolution of our transplant center, majority of patients with intimal dissection were first noted after the graft was already reperfused. At this time, access to supraceliac aorta was limited, especially if large coronary vein/spontaneous shunts and significant splenomegaly were also present. In such cases, infrarenal aorta was a safer option. As experience with the use of infrarenal aorta matured, it was our preferred site for GSV implantation. In cases where intimal dissection of the artery was noted before implantation was begun, supraceliac aorta was assessed for its suitability. Although, use of supraceliac aorta would theoretically result in better orientation and straight alignment of GSV; the short length of supraceliac aorta, its proximity with diaphragmatic crura, and co-existence of gastroesophageal varices would make tissue dissection and vascular control

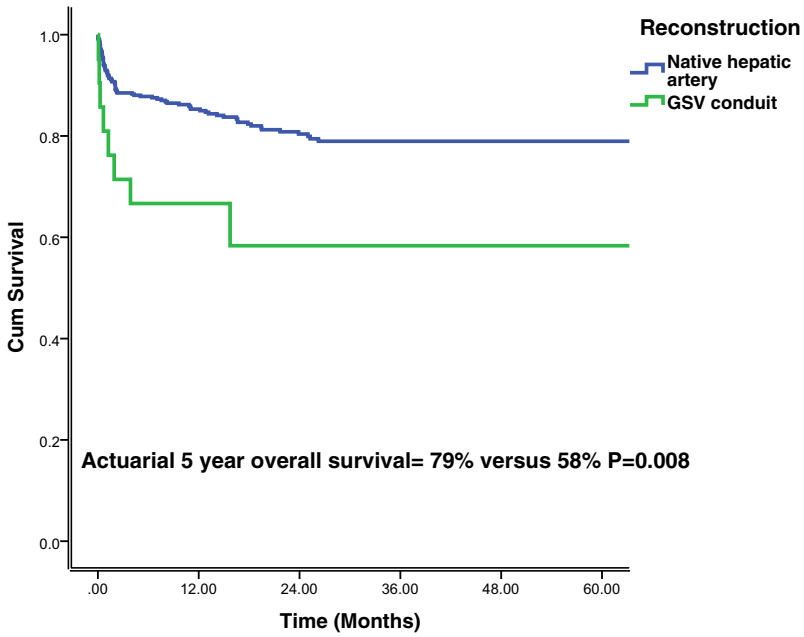

Fig. 4 Overall survival in patients who underwent arterial reconstruction using native hepatic arteries versus GSV inter positional conduits

Number at risk (months)	0	12	24	36	48	60
Group 1	452	282	181	81	31	4
Group 2	21	11	5	3	3	2

a difficult proposition. It was mandatory to have 15–20-cm long GSV procured for arterial inflow reconstruction with infra renal aorta. The left GSV was our preferred site since it allowed simultaneous preparation of aorta with surgeon operating on the aorta standing on the right and the one procuring GSV on the left of the patient. It can be argued that other options like testicular or ovarian vein can also be considered in these patients. Although interesting options, we do believe that this would lead to excessive retroperitoneal dissection in coagulopathic patients with liver failure.

Conclusion

The current study shows acceptable graft patency in patients undergoing LDLT with GSV interposition for arterial reconstruction. Despite excellent graft patency rates, management of postoperative bleeding and biliary complications remains challenging and reduces both short- and long-term survival. Judicious use of heparin in the postoperative period, use of broad-spectrum antibiotics in patients with biliary complications, and reduction in duration of interruption to hepatic artery inflow may improve survival in these patients. Every attempt should be made to preserve native hepatic arteries during recipient hepatectomy. In the absence of other options for arterial reconstruction, GSV conduits remain a viable option and can both save the graft and patient's life in urgent situations.

Authors' contributions Abu Bakar Hafeez Bhatti contributed to study conception and design, acquisition of data, analysis and interpretation of data, rafting of manuscript, and critical revision of manuscript. Faisal Saud Dar contributed to study conception and design, drafting of manuscript, and critical revision of manuscript. Ammal Imran Qureshi contributed to study conception and design, acquisition of data, drafting of manuscript, and critical revision of manuscript. Siraj Haider contributed to acquisition of data, analysis and interpretation of data, and critical revision of manuscript. M Nasir Ayub Khan contributed to study conception and design, drafting of manuscript, and critical revision of manuscript.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval The hospital ethics committee approved the study and informed consent was taken from all participants.

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