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ORIGINAL ARTICLE

Repeat endovascular treatment of recurring hepatic artery stenoses in orthotopic liver transplantation

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Summary

Hepatic artery stenosis (HAS) is a complication that impacts the results of orthotopic liver transplantation (OLT). Interventional radiological techniques are important therapeutic options for HAS. The aim of this retrospective study was to evaluate the outcome of repeated radiological treatments in recurring HAS after OLT. Of the 941 patients who underwent OLT at our center from January 1998 to September 2010, 48 (5%) were diagnosed with HAS, 37 (77%) of whom underwent transluminal interventional therapy with the placement of an endovascular stent. Success rate, complications, hepatic artery patency and follow-up were reviewed. After stent placement, artery patency was achieved in all patients. Three patients developed complications, including arterial dissection and hematoma. HAS recurrence was observed in 9 patients (24%), and hepatic artery thrombosis (HAT) occurred in 4 (11%). Radiological interventions were repeated 10 times in 8 patients without complications. At a median follow-up of 66 months (range 10–158), hepatic artery patency was observed in 35 cases (94.6%). The 5-year rates for graft and patient survival were 82.3% and 87.7%, respectively. Restenosis may occur in one-third of patients after endovascular treatment for thrombosis and HAS, but the long-term outcomes of iterative radiological treatment for HAS indicate a high rate of success.

Introduction

Hepatic artery stenosis (HAS) is one of the most common vascular complications after OLT [1,2]. Various hypotheses, such as operative technical errors, vascular clamp injury, differences between donor and recipient vessel calibers and extrinsic compression, have been proposed to explain the occurrence of HAS [3,4]. Other etiologies may also include allograft rejection, microvascular injury associated with the cold preservation of the liver, a disrupted vasa-vasorum and underlying liver disease [5]. HAS may lead or contribute to hepatic artery thrombosis, biliary complications and graft loss [2,6–8]. The reported incidence of HAS is between 2% and 15% of OLT procedures [8–12], and this rate appears to be higher for LDLT or pediatric recipients because of difference between the graft and the recipient vessel calibers [10] Interventional radiological techniques are among the most important therapeutic options for HAS. However, few patients require repeated endovascular treatment, and there is no consensus regarding the optimal treatment for such cases.

The aim of this retrospective study was to evaluate the outcome of repeated radiological interventions for the treatment of recurring HAS after OLT.

Materials and methods

Patient background

From January 1998 to September 2010, 941 patients received OLT at our center. Forty-eight patients (5.1%)

were diagnosed with HAS. Six patients underwent simultaneous arterial and biliary surgical repair, and five patients underwent re-transplantation because of multiple complex intrahepatic HAS and biliary strictures [13]. Thirty-seven patients (77.1%) underwent transluminal interventional therapy with the placement of an endovascular stent. Of these 37 patients, 29 were male and 8 were female. The mean age of the patients was 48.0 years (range, 19–66). The patient background details are summarized in Table 1. For each procedure, written or oral informed consent was obtained from the patients. Patient data were retrieved from the unit's institutional database, and a review of the patients' charts, radiology imaging studies and interventional procedures was performed.

Operation and immunosuppression

Of the 32 primary transplants, 30 were whole livers from deceased donors, 1 was a living donor liver transplantation (LDLT) and 1 was an auxiliary partial orthotopic liver transplantation (APOLT) for the treatment of fulminant hepatitis B virus. The LDLT was performed for hepatocellular carcinoma related to hepatitis C virus (HCV) beyond the Milan criteria, and the procedure was adult-adult (right lobe graft), ABO compatible and from a related donor (brother-brother). Re-transplantation was performed in five patients, including three with recurrent HCV, 1 with chronic rejection and one who experienced a recurrence of primary biliary cirrhosis (PBC).

There were no instances of liver donations following cardiac death, and 24 donors were over 60 years of age. No OLT was performed with an ABO-incompatible organ, and no recipient was affected by thrombocytemia. The mean time of cold ischemia was 8 h 52 min (range: 5 h 30 min to 11 h) and lasted >8 h in 48% of the procedures (n = 18). These procedures were performed by four different senior surgeons. The donor hepatectomy and recipient operations were performed using standard techniques [14–16]. Arterial anastomosis was performed with 7–0 or 8–0 polypropylene running sutures after portal reperfusion. All of the anastomoses were performed using ×2.5 magnification. The level of the anastomosis depended on the size, anatomy and quality of the hepatic arteries of the donors and recipients. Doppler ultra sonography (DUS) was performed prior to closure of the abdomen following OLT. The patients received immunosuppressive treatment with different regimens based on calcineurin inhibitors (cyclosporine or tacrolimus), azathioprine, mycophenolate mofetil and prednisolone. An antiplatelet drug (acetylsalicylic acid) was administered at 100 mg/day from post-transplantation day 7 and for life.

Post-transplant follow-up

To evaluate vascular patency, all of the patients underwent daily DUS during the first week post-OLT, followed by once every 2 days during the second week, once a week after the third week until discharge and once every 6 months thereafter. Each time an abnormality in serum liver function tests, which was unexplained by other findings, was observed, DUS was performed. Resistive index measurements [(maximal systolic velocity-end diastolic velocity)/maximal systolic velocity] and the systolic ascending time of the hepatic arteries were routinely recorded. HAS was suspected when the resistive index value was less than 0.5 and/or the systolic ascending time was greater than 10 ms.

In cases of DUS abnormality, computed tomographic angiography or hepatic artery angiography was performed to verify the arterial patency. A diagnosis of HAS was considered if the luminal diameter of the artery was decreased by >50%. If complete hepatic arterial thrombosis (HAT) was observed very early post-transplantation (within 1–7 days), surgical treatment was performed. Patients with a complete hepatic artery occlusion were not included in this study.

Radiological treatment

All of the interventional radiological treatments were performed at the Department of Radiology, Beaujon Hospital [9]. In most cases, a 6-French sheath was placed with a transfemoral approach proximal to the stenosis. Selective arteriography with the use of digital subtraction imaging was carried out to obtain the details of the HAS. The stenosis was crossed with a 0.014-inch guidewire (PT Graphics; Boston Scientific, Boston, MA, USA). After balloon dilatation, NIR coronary stents were implanted (Scimed Boston Scientific, La Garenne Colombes, France), although Tsunami coronary stents (Terumo, Tokyo, Japan) are the most commonly used type. The sizes of the stents were determined based on the automatic measurement of vessel size using the sheath diameter as a reference. During the procedure, the patients received heparin (2500–5000 units according to weight) and a vasodilatator. Anticoagulant therapy was not routinely maintained after the procedure.

Outcomes

The outcomes of repeated interventional treatment for recurring HAS were evaluated for complications during the procedure, further hepatic artery complications, biliary complication and graft and patient survival. The arterial cumulative patency rate, the biliary complication-free rate

Table 1. Summary of patient characteristics.

Age(years)/ Gender	LT type	TI post LT (days)	Site of anatomosis*	Site of HAS	Complication post 1st stent (TI post stent)	Re-procedure post 1st stent	Biliary complication (TI post LT)/treatment	Outcome
60F	DDLT	71	1	Anast.	–	–	–	D(78M), Renal failure
35M	DDLT	67	1	Anast.	–	–	–	D(27M), Recurrent PSC
52F	DDLT	85	1	Anast.	Re-HAS(288 days)	Balloon	–	A(158M)
58M	DDLT	220	1	Anast.	–	–	AS(190 days) Stent	D(10M), Sepsis
48M	DDLT	52	1	Tandem.	–	–	AS(30 days) Observation	A(156M)
54M	DDLT	20	1	Anast.	–	–	–	A(155M)
51M	DDLT	14	1	Anast.	Re-HAS(115 days)	Balloon	–	A(155M)
54M	DDLT	48	1	Anast.	–	–	–	A(153M)
28M	APOLT	56	3	Anast.	–	–	–	A(152M)
54M	DDLT	44	1	Anast.	–	–	–	D(44M), Recurrent AC
34F	DDLT	60	1	Anast.	HAT(6 days)	Thrombolysis,	NAS(360 days), ReLT	A(150M), ReLT(38M) IC
31F	DDLT	18	1	Anast.	Re-HAS(125 days)	Re-anastomosis	Biliary fistula(4 days) Re-anastmosis	A(147M)
53F	DDLT	90	1	Anast.	–	–	–	D(44M), Pulmonary Ca.
39M	DDLT	55	1	Anast.	Re-HAS(65 days)	stent	NAS(49 days) Observation	A(135M)
63M	DDLT	55	1	Anast.	–	–	Biliary fistula (2 days)	D(68M), Ca. of tongue
51M	DDLT	180	1	Anast.	–	–	–	A(128M)
51M	DDLT	25	1	Anast.	Re-HAS(118 days)	Balloon	AS(120 days) Stent	A(125M)
36M	DDLT	21	2	Ex-Anast.	–	-	–	A(102M)
44M	DDLT	73	2	Anast.	Re-HAS(128 days)	Balloon	–	A(95M)
43M	DDLT	16	1	Anast.	HAT(22 days)	Thrombolysis	–	A(95M)
44M	ReLT	150	2	Anast.	–	–	AS(160 days) Stent	A(92M)
48M	DDLT	30	1	Anast.	Re-HAS(64 days)	Stent	AS(30 days) Stent	A(85M)
40M	DDLT	38	1	Anast.	Re-HAS(236 days, 499 days)	Balloon x2	–	A(66M)
62M	DDLT	98	1	Anast.	Re-HAS(177 days, 359 days)	Balloon x2	–	A(65M)
48M	ReLT	11	2	Anast.	–	–	–	A(64M)
44M	LDLT	26	1	Anast.	–	–	NAS(26 days), ReLT	A(59M), ReLT(59M) IC
40M	ReLT	24	2	Anast.	–	–	Biliary fistula(6 days) Re-anastmosis	A(57M)
58M	DDLT	22	1	Anast.	–	–	–	A(53M)
19F	ReLT	120	2	Anast.	HAT(20 days)	Observation	Biliary fistula(7 days) Re-anastomosis	A(52M)
51M	DDLT	17	1	Anast.	–	–	–	A(48M)
48M	DDLT	210	1	Anast.	–	–	–	A(41M)
44F	DDLT	26	1	Tandem.	–	–	AS(177 days) Stent	A(41M)
57F	DDLT	15	1	Anast.	–	–	–	A(39M)
66M	ReLT	30	1	Anast.	–	–	–	A(38M)
56M	DDLT	114	1	Anast.	–	–	–	A(28M), ReLT(14M) CR
53M	DDLT	21	1	Tandem.	–	–	–	A(25M)
59M	DDLT	6	1	Ex-Anast.	HAT(9 days)	Observation	–	A(20M)

*1: end-to-end (donor and recipient:Hepatica communis); 2: end-to-side (donor: Hepatica communis and recipient: Hepatica communis + gastroduodenalis-patch); 3: donor iliac arterial graft (donor hepatica communis and recipient Aorta).

TI, time interval; LT, liver transplantation; DD, deceased donor; LD, living donor; ReLT, re-transplantation; Anast., anastomosis; Ex-Anast., extra-anastomosis; AS, Anastomotic stricture; NAS, NonAnastomotic stricture; PSC, primary sclerosing cholangitis; AC, alcoholic liver cirrhosis; IC, ischemic cholangitis; D, death; A, alive; Ca. carcinoma; CR, chronic rejection.

and the graft and patient survival rates were determined using the Kaplan–Meier method.

Results

Hepatic artery stenosis was diagnosed between 6 and 220 days after OLT (mean, 60.2 days). The median follow-up period of these patients was 66 months (range: 10–158 months). Thirty cases of HAS (81.1%) were detected within 3 months after OLT. HAS was suspected because of elevated liver enzymes in 17 patients (45.9%) and specific symptoms in 5 patients (13.5%) (fever $n = 3$, jaundice $n = 2$). In addition, 15 patients (40.5%) had HAS detected after routine DUS and were asymptomatic with no abnormal blood test results.

Hepatic artery stenosis was located close to the anastomosis in 32 cases (86.5%), at an extra-anastomotic site in two cases (5.4%) and at tandem sites (anastomotic and extra-anastomotic site) in three cases (8.1%). Anastomosis was performed in 30 cases using an end-to-end technique (donor and recipient: hepatica communis) and in six cases using an end-to-side technique (donor: hepatica communis and recipient: hepatica communis + gastroduodenalis-patch). A donor iliac arterial graft was used in one patient between the donor hepatica communis and the recipient aorta. For the two cases of extra-anastomotic HAS, the HAS was located in the hepatica communis of the recipient and was likely because of a clamp injury. In the patients with tandem stenoses ($n = 3$), we found in all cases an anastomotic lesion with a lesion distal to the anastomosis ($n = 6$). All 37 patients underwent transluminal interventional therapy with an endovascular stent. A single stent was used in 29 patients (78.4%), two stents were used in seven patients, and three stents were used in one patient. Hepatic arterial patency was successfully achieved as a result of stent placement in all of the cases. There were three complications noted during the procedures. One patient who had APOLT developed an arterial dissection of segment VI after stenting the right hepatic artery without affecting the clinical outcome; this patient is still alive 12 years after the transplantation without biliary complication or graft loss. In addition, two patients had a hematoma that developed in the femoral puncture site.

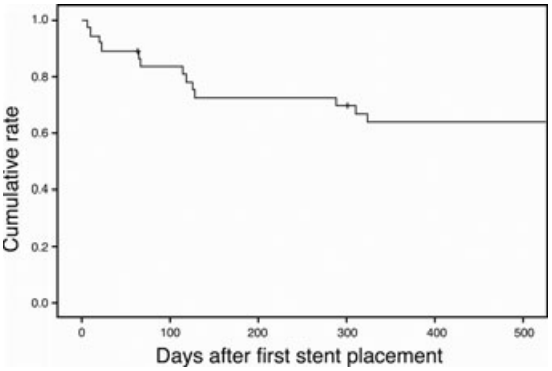

Figure 1 Kaplan–Meier curves for the arterial patency rate after the first stent placement.

Twenty-four patients (64.8%) did not have further arterial complications after stent placement (the median follow-up period was 41.2 months, range: 2–142 months). The other 13 patients (35%) developed subsequent hepatic arterial complications; of these, nine patients (75%) had recurrent stenosis in the same site as the first lesion, and four patients had HAT (30%). The mean time interval between the stent placement and the recurrent stenosis was 170.7 days (range: 64–323 days). The mean time interval between stent placement and HAT was 16.7 days (range: 9–22 days). The arterial complication-free survival after the first stent placement is shown in Fig. 1.

The nine patients who developed recurrent HAS were successfully treated. Balloon dilatation was performed in six patients, re-stenting was performed in two patients, and re-anastomosis was performed in one patient.

We chose to perform re-anastomosis in one patient because of the need for simultaneous biliary reconstruction because of biliary anastomotic stricture [5]. There were no immediate complications during these procedures. However, two patients who underwent balloon dilatation subsequently developed a recurrent stenosis at 182 and 263 days after the second IVR procedure.

These patients were treated with a secondary balloon dilatation, and they remained alive without further compli-

Table 2. Summary of arterial treatments.

	HAS		IVR treatment				Surgical revision
	Case (total)	Case (Stent/PTA)	Immediate complication	Restenosis	HAT	Arterial patency	Case
1st treatment	37	37 (37/0)	3 (8.1%)	9 (24.3%)	4 (10.8%)	64.9%	0
2nd treatment	9	8 (2/6)	0	2 (22.2%)	0	75.0%	1
3rd treatment	2	2 (0/2)	0	0	0	100%	0
total	48	47 (39/8)	3 (6.4%)	11 (23.4%)	4 (8.5%)	94.6% (overall)	1

Table 3. Literature experience of HAS endovascular treatment.

Author (years)	No. pts	LT type	LT time (mean months)	Stenosis type	Procedures			Technical success	Complication rate	Follow- up (mean months)	Restenosis
					PTA	STENT	PTA + STENT				
Orons (95)	19	WLT	3.8	A: 86% IH: 9.5% T:5%	21	–	–	81%	9.5%	16	/
Saad (05)	42	/	4.2	A: 52% ExA: 23% T: 25%	42	–	–	81%	12%	19	32%
Ueno (06)	26	WLT	6.7	A: 100%	0	26	–	100%	23%	31 ± 14	36%
Kodama (06)	18	LDLT	1.3	A:100%	30	–	–	93.3%	6.7%	26	33.3%
Chen (09)	20	WLT	3	A: 80% IH: 15% rHA: 5%	4	1	15	100%	/	14.4 ± 8	15%
Maruzzelli [10]	25	WLT:15 SLT: 9 LDLT: 1	1.8	A: 92% T: 8%	13	–	15	96%	16%	15.8	20%
Lastovickova [11]	19	WLT	2.7	A: 63% IH: 11% T: 16% CA: 10%	6	–	16	100%	4.5%	30	0%
Our experience	37	WLT: 30 LDLT: 1 APOLT: 1 ReTX: 5	2	A: 32% ExA: 5.4% T: 8.1%	–	–	47	100%	6.4%	66	24.3%

WLT, whole-liver transplantation; LDLT, living donor liver transplantation; SLT, split liver transplantation; APOLT, Auxiliary Partial Orthotopic Liver Transplant; ReTx, re-transplant; A, anastomotic; ExA, extra-anastomotic; IH, intrahepatic; T, tandem; CA, celiac artery; rHA, recipient hepatic artery.

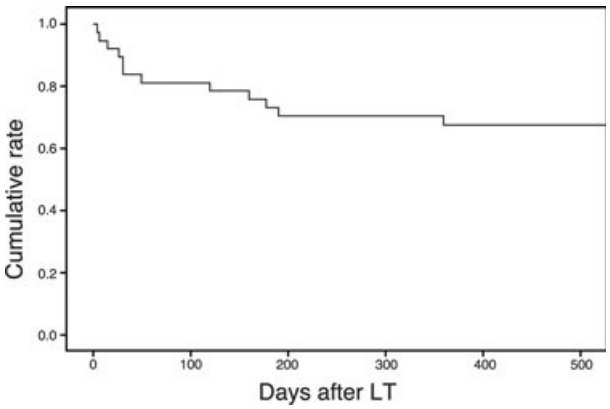

Figure 2 Kaplan–Meier curves for the biliary complication-free rate after liver transplantation.

cations. Four patients with HAT were treated with anticoagulation and antiplatelet agents, and one of these four patients developed severe ischemic cholangitis and underwent a re-transplantation at 38 months after the primary OLT.

Overall, 47 endovascular interventional treatments were performed for HAS (Table 2).

Complications during the endovascular treatment were observed in three cases (6.4%). Overall, hepatic artery patency after repeated IVR treatments was obtained in 35 patients (94.6%). Among the 37 patients with arterial complications, biliary complications occurred in 13 patients (35.1%). These biliary complications were diagnosed between 4 and 360 days after the OLT (mean 97.2 days) Table 3.

The biliary complication-free survival rate after OLT is shown in Fig. 2. Four patients developed a biliary fistula immediately after the OLT; of these, three were anastomotic, and one was in the cut liver surface. In addition, nine patients developed bile duct strictures; of these, six were anastomotic, and three were nonanastomotic.

Overall, three patients underwent re-transplantation after developing arterial complications.

The indications of re-transplantation included biliary stricture ($n = 2$) and chronic rejection ($n = 1$). The actuarial graft survival rates at 1, 3 and 5 years were 97.3%, 91.7% and 82.3%, respectively (Fig. 3a). Six patients died, either because of a recurrence of their primary disease ($n = 2$), a malignancy ($n = 2$), renal failure ($n = 1$) or sepsis ($n = 1$).

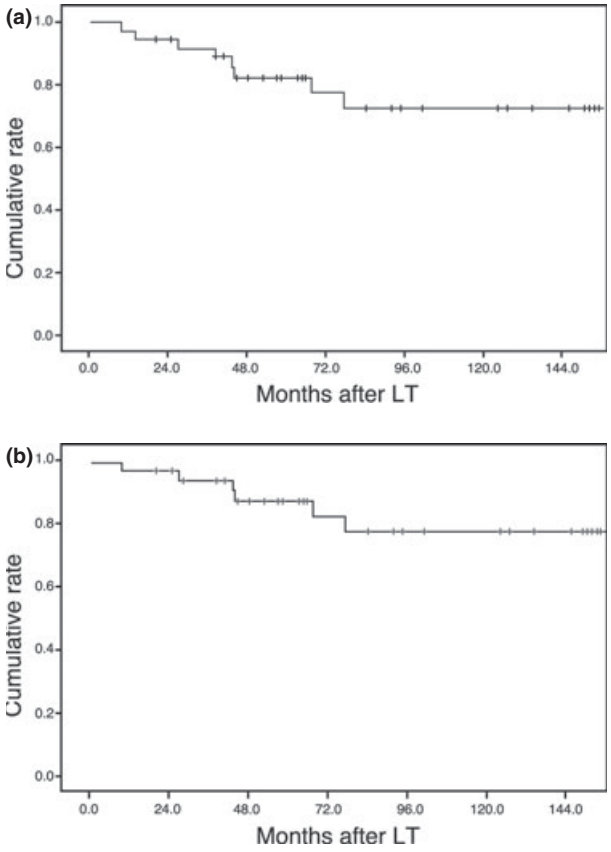

Figure 3 (a) Graft survival after LT. (b) Patient survival after LT.

In all six of these patients, the hepatic artery was patent on the assessment prior to death. The actuarial patient survival rates at 1, 3 and 5 years were 97.3%, 94.4%, and 87.7%, respectively (Fig. 3b).

Discussion

In the present series, the incidence of HAS was 5.1%. The clinical presentation of HAS usually includes a deterioration of graft function with an elevated level of liver transaminases; however, the incidence of asymptomatic HAS has been found to be as high as 20–27% [5,7]. Routine DUS is one of the best tools for detecting silent HAS in patients, although its sensitivity is close to 85% [5,17,18]. In the present series, 41% of the patients were asymptomatic, but were identified because of our policy to routinely perform DUS after an OLT to detect HAT, a serious complication that compromises long-term graft function and survival if left untreated [6,19–21]. The main objectives of this policy were to attain better detection and treatment in cases of HAS and better prevention against HAT. Saad *et al.* reported that HAT was observed in 65 ± 13% of untreated HAS cases within 6 months, whereas HAT was observed in 19 ± 8% of cases in the same period where the successful endoluminal treatment of HAS was achieved [6]. Although rare cases of spontaneous neovascularization after arterial thrombosis have been reported [22], the treatment for HAS has traditionally included anticoagulation, surgical revascularization and re-transplantation [8]. Recently, encouraging results of endoluminal treatments for HAS, such as angioplasty and stent placement, have been reported [6,7,10,23–26]. Abbasoglu *et al.* [8] reported the results of the arterial treatment for HAS in 39 patients with 41 allografts. In the 35 patients who underwent surgical treatments, complete occlusion of the hepatic artery after treatment occurred in 9 patients (25.7%); restenosis did not occur in the patients who were highly selected for endoluminal revision. In the renal transplantation setting, surgical revascularization for renal artery stenosis is limited to patients with failed transluminal treatment or severe kinking, as this surgery is associated with higher rates of morbidity, such as graft loss and ureteral injury, as well as mortality in up to 5% of cases, whereas the success and restenosis rates of hepatic artery surgery is similar to percutaneous transluminal angioplasty (PTA) with stenting [27]. To our knowledge, there has been no prospective study demonstrating the superiority of endoluminal treatments compared to surgical treatments. However, it is certain that the endoluminal procedure plays a predominant role in the treatment of HAS.

The superiority of stent placement or balloon angioplasty as the primary means to treat HAS is controversial. Concerning treatments with an IVR procedure, the reported rates for restenosis have ranged between 0% and 28% [28,29]. However, Saad *et al.* [20] reported that restenosis after a stent placement occurred at a later date in comparison with restenosis in lesions treated with angioplasty. In addition, Heublein *et al.* [30] reported that the treatment of coronary artery stenosis after heart transplantation with the placement of a stent led to a greater improvement in luminal area when compared withangioplasty. In this previous study, the rate of restenosis was 25% after stenting, whereas the reported rates after balloon angioplasty were between 50% and 60%. Leertouwer *et al.* [31] described a meta-analysis of renal arterial stent placement in comparison with renal PTA in patients with transplant renal arterial stenosis and suggested that stent placement had a higher technical success rate and a lower restenosis rate in comparison with angioplasty alone (98% vs. 77% and 17% vs. 26%, respectively). Although these results are encouraging, the data cannot be translated into the liver transplantation setting because of differences in the types of anastomotic techniques and different characteristics of flow and the vascular resistance. Nevertheless, even if stent placement is difficult in some cases of HAS, e.g. in small-diameter arteries or severely kinked arteries [9], we expect that the use of

stents will reduce the risk of further arterial complications, such as arterial rupture and dissections, and that the superiority of stent placement over balloon angioplasty alone will be proven in appropriately selected patients in future studies.

In this study, repeated IVR treatments for recurring HAS were performed; in total, 48 IVR treatments were administered to 37 patients. Twenty-nine patients underwent IVR treatment once, six patients underwent IVR treatment twice, and two patients required a third IVR treatment. Overall, 94.6% of patients achieved hepatic artery patency during follow-up after repeated IVR treatment. The administration of repeated IVR treatments for iterative HAS has previously been reported. For example, Kodama *et al.* [10] obtained excellent results with repeated PTA for HAS following LDLT. In this previous study, 18 patients underwent 30 procedures in total without an increased complication rate, and these authors demonstrated that arterial patency was achieved in all cases as a result of repeated PTA.

Complications related to IVR treatment were reported in 7–10% of the patients. These complications included hepatic artery rupture or perforation, thrombosis, dissection, spasm and pseudo-aneurysm. In this study, we experienced three complications among 48 procedures (6.4%), and this rate is in concordance with rates previously reported in the literature (0–21%) [6,7,9,10,12]. However, one out of the three patients who experienced complications after IVR required re-transplantation because of severe ischemia cholangitis. Biliary complications associated with HAS and hepatic artery occlusion are well established, and the incidence of biliary complications among HAS patients is generally between 22% and 54% [7–9,11,12,32]. Indeed, the exclusive source of the vascular supply to the allograft biliary system originates from the hepatic artery supply. In patients with HAS, the development of biliary complications are therefore expected and have a significant impact on graft and patient survival. Abbasoglu *et al.* [8] reported that patients with HAS were twice as likely to have biliary complications as compared to patients without HAS. Moreover, Orons *et al.* [25] demonstrated that markedly elevated liver enzyme levels at presentation were associated with an increased risk of re-transplantation or death, regardless of the outcome of the endovascular treatment. As a consequence, detecting and treating HAS prior to the development of biliary complications and graft dysfunction would likely have a marked impact on clinical outcome. In the present series of patients, the policy for the routine performance of DUS led us to detect HAS up to an average of 60 days after OLT, and 49% of the detected HAS cases were asymptomatic. However, in our study, the incidence of biliary complications remained high (35%), which may have been because of the fact that these complications were not exclusively because of the arterial blood supply but were likely to have had a multifactorial etiology, including complications with the arterial blood supply.

In this study, the 5-year graft success and patient survival rates were 82.3% and 87.7%, respectively. We believe that these encouraging results were due in part to the fact that all of the patients were followed up routinely post-OLT with DUS and the generous use of CT-angiography and interventional techniques. The early diagnosis of HAS followed by early treatment avoids the development of some life-threatening biliary complications and graft loss, especially in asymptomatic patients. As a result, this DUS policy has led to great benefits from the acquired experience of interventional radiologists and the innovation and refinement of their materials and techniques in the setting of a multidisciplinary approach.

In conclusion, the majority of HAS cases after OLT were successfully treated using stent placements with a low morbidity rate, although hepatic artery restenosis occurred in one-third of the patients. Repeated endovascular treatments for recurring hepatic artery complications were feasible with a high success rate and contributed to favorable long-term results.

Authorship

SD: designed research/study, wrote the paper. TA and BO: collected data, analyzed data. FD and FC: contributed important reagents. SA: performed research/study, wrote the paper. DF: analyzed data, wrote the paper. FS: collected data. BJ: designed research/study, performed research/study.

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