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SAFETY AND EFFICACY OF THE ENDOVASCULAR INTERVENTIONAL THERAPY FOR HEPATIC ARTERY COMPLICATIONS AFTER LIVER TRANSPLANTATION

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ABSTRACT

Aim: To analyze the safety and efficacy of endovascular interventional treatment for hepatic artery complications after liver transplantation (LT). **Materials and methods:** Twelve patients who have undergone endovascular interventional treatment for the hepatic artery complications after liver transplantation were retrospectively analyzed. Techniques included catheter-directed thrombolysis, percutaneous transluminal angioplasty and stent placement. Lesion characteristics, treatment techniques and outcomes were depicted and evaluated. **Results:** Five patients developed hepatic artery thrombosis, three patients developed hepatic artery stenosis, two patients developed HAT combined with HAS and two patients developed hepatic artery pseudoaneurysm. Ten patients were successfully treated, the primary technical success rate was 83% (10/12). Two cases were observed with complications during the procedure and treated subsequently. One patient was complicated by rupture during PTA and was treated with a graft-covered stent. Serum alanine aminotransaminase, aspartate aminotransferase, total bilirubin and direct bilirubin decreased remarkably ($P < 0.01$) two weeks after the treatment. All successfully treated cases were followed up for 2-24 months, two patients underwent a repeated treatment due to restenosis and acute thrombosis after the operation. **Conclusion:** Endovascular interventional treatment is a safe, effective and minimally invasive technique and can be regarded as the first-line treatment for hepatic artery complications after LT for selected patients.

KEYWORDS: Hepatocellular carcinoma, Transarterial chemoembolization, liver transplantation, Complications, Hepatic artery, Endovascular therapy.

INTRODUCTION

Liver transplantation (LT) has been the standard line of treatment for the patients with end-stage liver disease and has significantly improved the survival rate of the patients. However, vascular complications, especially the hepatic artery complications after liver transplantation can seriously threaten the survival of patients and need effective strategies to avoid graft loss and re-transplantation. Surgical revascularization is identified as the first choice to treat vascular complications, but it is an invasive method and cannot be applied to patients with a poor physical condition. With the rapid development of interventional radiology, endovascular interventional therapy has been used to treat vascular complications in recent years.[1,2] However, the techniques remain controversial, especially in the early period after the liver transplantation due to the potential risks of haemorrhage.[3,6] In this article, we reviewed the clinical and laboratory data of twelve patients treated in our department to evaluate the outcomes of endovascular interventional therapy for adult patients with hepatic artery complications after liver transplantation.

MATERIALS AND METHODS

Clinical data: The institutional review board of the Zhongnan Hospital of Wuhan University approved this retrospective study and waived the requirement for patient informed consent. Twelve patients (3 females and 9 males) with hepatic artery complications after LT in our hospital between January 2010 and February 2015 were retrospectively reviewed. The mean age was 45.3 years (range: 40-66 years). The primary liver disease for recipients were as followed: hepatitis B virus-associated liver cirrhosis combined with hepatocellular carcinoma (HCC) in 5 cases, hepatitis B virus-associated liver cirrhosis in 2 cases, alcoholic-associated liver cirrhosis in 2 cases, intrahepatic cholangiocarcinoma in 1 case, primary biliary cirrhosis in 1 case, and acute liver failure in 1. Detailed clinical data were summarized in Table 1. Routine bedside color doppler sonography (CDS) was performed for all cases after liver transplantation twice a day during the first week, once a day during the second week, once a week during the third to the fourth week, once a month during the second to the third month and once every two months afterwards. In the meantime, the liver function was tested on a regular basis.

Table 1: Demographic data of the study patients prior to endovascular interventional therapy for hepatic artery complications after liver transplantation.

Characteristics	Patients
Gender	
Male	3(25%)
Female	9(75%)
Age (years)	40-66(mean, 45.3)
Primary disease	
HBV, LC, HCC	5(42%)
Alcoholic LC, HCC	2(17%)
HBV, LC	2(17%)
ALF	1(8%)
PBC	1(8%)
ICC	1(8%)
IT between LT to HAC (days)	4-103(mean,52.4)

HBV: hepatitis B virus; LC: liver cirrhosis; ALF: acute liver failure; PBC: primary biliary cirrhosis; ICC: intrahepatic cholangiocarcinoma; IT: interval time; HAC: hepatic artery complications.

Diagnosis of hepatic artery complications

When abnormal liver function or hepatic artery flow signals by routine color doppler sonography (CDS) was observed after liver transplantation, multidetector computed tomographic angiography (MDCTA) or magnetic resonance angiography (MRA) was subsequently performed to further detect hepatic vessel lesions. If MDCTA or MRA revealed abnormal hepatic artery vessels, emergent digital subtraction angiography (DSA) was performed to confirm the lesions location and characteristics and undergone corresponding treatment. Finally, five patients developed hepatic artery thrombosis (HAT), three patients developed hepatic artery stenosis (HAS), two patients developed HAT combined with HAS and two patients developed hepatic artery pseudoaneurysm(HAP).

Techniques of endovascular interventional therapy:

Under local anaesthesia, percutaneous right femoral artery puncture intubation was done with modified seldinger technique followed by insertion of a 5F-Cobra catheter and positioned it in the celiac axis to perform angiography at different angles. If hepatic artery complications were confirmed through hepatic arterial angiography, endovascular interventional treatment was performed subsequently. Blood pressure, electrocardiogram and blood oxygen saturation were monitored during operation.

Once hepatic artery thrombosis (HAT) was confirmed by initial angiography, the guide-wire was inserted and pushed forward to pass through the thrombus and a 5F infusion catheter (Cook) was placed near the thrombus of the hepatic artery with a coaxial 0.035-inch infusion wire. Initially, bolus injection of urokinase at a dose of 250,000U was performed slowly through the 5F catheter for 30 minutes. Then the transcatheter micro-pump continuous infusion of urokinase (30,000-60,000U/24h) was employed for 1-5 days until the thrombosis was completely dissolved. Angiographic re-examination was performed through the preserved catheter to observe whether complete patency of the hepatic artery has been restored for every 24 hours. If angiography confirmed successful patency, the preserved catheter and sheath pipe was removed and catheter-directed thrombolysis (CDT) was ceased. If the hepatic artery could not be opened until the fifth day, CDT was also ceased to avoid the risk of bleeding.

If angiography revealed significant HAS (>50%), the position of the stenosis, degree, length and normal hepatic artery diameter were calculated. Percutaneous transluminal angioplasty (PTA) and selected stent placement were performed. Briefly, heparin at a dose of 3000-5000U was injected, followed by placement of a 7F renal double-curve (RDC) guiding catheter (Boston Scientific, Natick, Mass) in the narrow segment. A 0.014-inch moderate micro guidewire (Boston Scientific) was passed through the stenosis, low-profile coronary angioplasty balloons (3mm-5mm in diameter; Boston Scientific, Galway, Ireland) were chosen to place atthe center of the narrow segment according to different artery diameters. If PTA is invalid (hepatic artery remained stenotic more than 20%), balloon-expandable coronary stent (3.5mm-4.5mm in diameter; Boston Scientific, Galway, Ireland) placement was performed. Stent location and hepatic artery patency were reviewed post-operation through angiography.

For patients with hepatic artery pseudoaneurysm (HAP), a 7F renal double-curve (RDC) guiding catheter (Boston Scientific, Natick, Mass) was fixed near the lesion first, then a SP 3F coaxial microcatheter (Terumo, Japan) was inserted into the narrow place. A 0.014-inch micro-guidewire was exchanged to pass through the narrow place and transluminal angioplasty was performed by using a micro-balloon (2mm×15mm), then two stent-grafts were placed, overlapping at the artery fistula for 20mm.

Intraoperative and postoperative protocols

During thrombolytic and percutaneous transluminal

angioplasty (PTA) procedure, anticoagulation therapy was performed by subcutaneous injection of low molecular weight heparin (5000U/12h). At the same time, prothrombin time (PT), activated partial thromboplastin time (APTT) and the international normalized ratio (INR) were closely monitored to maintain INR at 2.0 to 2.5. After hepatic artery patency by thrombolytic therapy and stent placement, low molecular weight heparin (6000U/d) was given for one week and oral aspirin (100mg/d) for three to six months. All cases underwent color doppler sonography (CDS) or once at 1-7 days postintervention, then routinely at 1, 3, 6 and 12 months and yearly thereafter.

Statistical Analysis

Statistical analysis were done by using SPSS 21.0 version (IBM, Chicago, IL) statistical analysis software. All data of continuous variables are expressed as mean±standard deviation. A probability value of $P \leq 0.05$ was considered statistically.

RESULTS

All cases were confirmed with hepatic artery complications after LT through angiography. The mean interval between LT and occurrence of hepatic artery complications was 52.4 days (range：4-103 days). These including HAT (n=5; Fig 1), HAS (n=3), HAT combined HAS (n=2; Fig 2) and HAP (n=2; Fig 3). Five patients with HAT showed complete occlusion of the proper hepatic artery. Five patients with HAS showed a degree of stenosis range from 70% to 90%. And two patients with HAP showed extrahepatic pseudoaneurysm. Ten patients were successfully treated, initial techniques included CDT (n=5), PTA alone (n=1), PTA combined with stent placement (n=5).

The primary technical success rate was 83% (10/12). One rupture was seen in one patient during the initial PTA and was managed by graft-covered stent placement. In one patient with HAT, a slight bit of bleeding (<100ml/24h) was found in the process of thrombolysis, CDT was immediately suspended and conservative treatment was given, at the same time, patients' symptoms and vital signs were observed closely. Small doses of urokinase were sequentially infused after the hemorrhage was controlled. The overall incidence of complications during the operation was 20% (2/10). Characteristics of endovascular interventional treatment for patients with hepatic artery complications were listed in Table 2.

Table 2: Characteristics of hepatic artery complications of the interventional therapy.

Case No.	Vascular complication	Interventional management	Urokinase (U/h)	Duration (hour)	Balloon diameter (mm)	Stent (mm)	No. of stents	Procedural complication	Follow up(day)	Outcome
1	HAT*	CDT	40,000	48	no	no	-	no	750	Patency
2		CDT	50,000	24	no	no	-	no	356	Patency
3		CDT	30,000	24	no	no	-	no	186	Died
4		CDT	60,000	72	no	no	-	no	378	Patency
5	HAS	PTA+stent	50,000	48	3.5×20	4.0×20	-	hemorrhage	486	patency
6		PTA+stent	no	-	3.0×15	3.5×20	1	no	106	Died
7		PTA	no	-	5.0×20	no	-	no	60	Died
8	HAT & HAS	CDT+PTA+stent	50,000	48	4.0×20	4.5×30#	1	rupture	264	Patency
9		CDT+PTA+stent	30,000	72	3.5×15	no	1	no	254	Patency
10	HAP	stent	no	-	2.0×15	4.5×30#	2	no	114	Died
Mean±SD			48.0±19.6					295.4±208.8		

CDT: catheter-directed thrombolysis; PTA: percutaneous transluminal angioplasty; ES: endovascular stenting; *total thrombus occlusion of hepatic artery; # graft-covered stent; & (combination).

In one case of complete hepatic artery thrombosis(HAT), catheter-directed thrombolysis (CDT) was failed due to long time (30 days after LT) formation of thrombus, surgical blood vessel revascularization was performed subsequently. In one patient with hepatic artery pseudoaneurysm (HAP), graft-covered stent placement was failed, because the full segment of hepatic artery was involved and the size of pseudoaneurysm was irregular. The graft-covered stent could not cover the full pseudoaneurysm, and re-transplantation was undergone subsequently. All cases were assessed by color doppler sonography (CDS) post-operation and no obvious abnormal hepatic arterial blood flow signals were observed and the mean resistance index (RI) was 0.46 (range: 0.47-0.54). Serum alanine aminotransaminase (ALT), aspartate aminotransferase (AST), total bilirubin (TBil) and direct bilirubin (DBil) decreased remarkably two weeks after treatment. Results before and after the therapy are listed in Table 3.

Table 3: Results obtained before and after the interventional therapy in ten patients.

LFT	Prior to treatment	Post-treatment (two weeks)	P value
ALT (U/L)	486.0±175.8	113.9±34.2	<0.01
AST (U/L)	315.6±99.8	81.7±21.6	<0.01
TBil (umol/L)	99.4±51.7	31.2±5.0	<0.01
DBil (umol/L)	80.7±23.8	29.7±6.9	<0.01

ALT: alanine aminotransaminase; AST: aspartate aminotransferase; TBil: total bilirubin; DBil: direct bilirubin; LFT: liver function test.

All successfully treated patients were followed up. Mean follow-up was 9.8 months (range: 2-25 months). Routine CDS revealed hepatic artery restenosis and thrombosis in two patients (20%) after initial PTA and stent placement. In one patient with HAS, Doppler US-suspected stenosis was observed 1 month after PTA alone and was successfully treated by a repeated PTA treatment. In another patient with HAP who developed acute thrombosis after placement of two covered stents, local thrombolysis was successfully performed. During follow up, one patient died of multiple organ failure, two patients died of recurrence of hepatocellular carcinoma, one patient died of severe abdominal infection. The mortality was 40% (4/10) in our group.

Figure 1

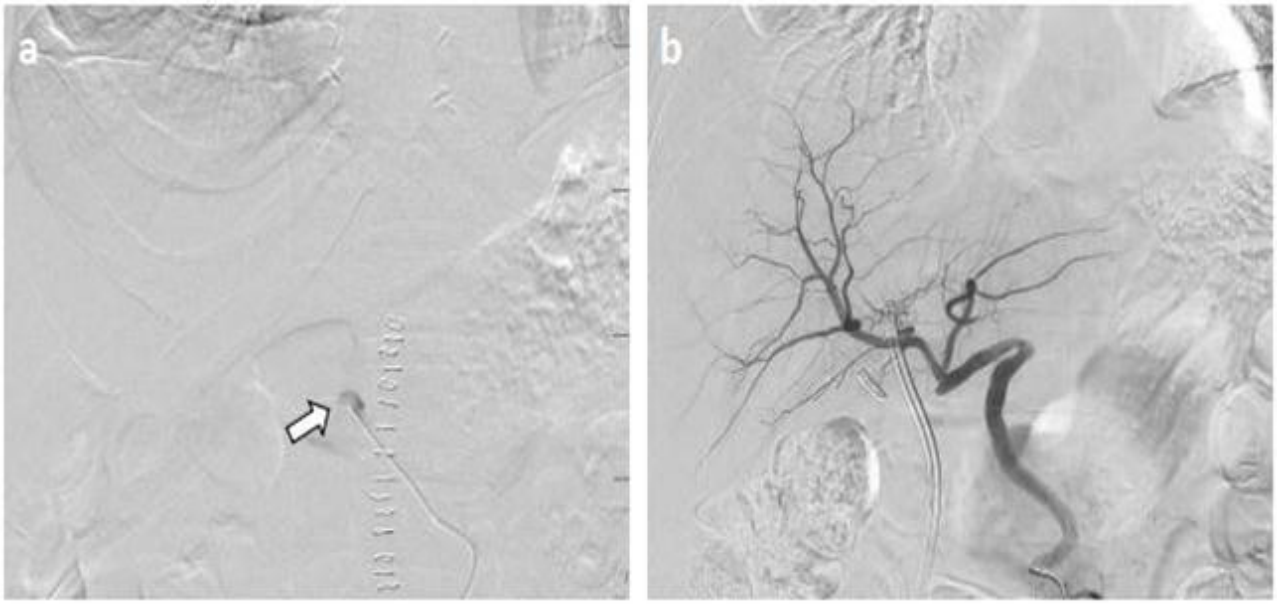

Figure 1: a, b. CDS performed on postoperative day 4 shows an interruption of the hepatic artery. Selective hepatic artery angiography reveals total occlusion after liver transplantation (a, arrow). Thrombolysis therapy performed with an initial bolus injection of urokinase through catheter combined with a transcatheter micro-pump continuous infusion of urokinase (40,000U/h) for 48 hours restores hepatic artery flow (b).

Figure 2

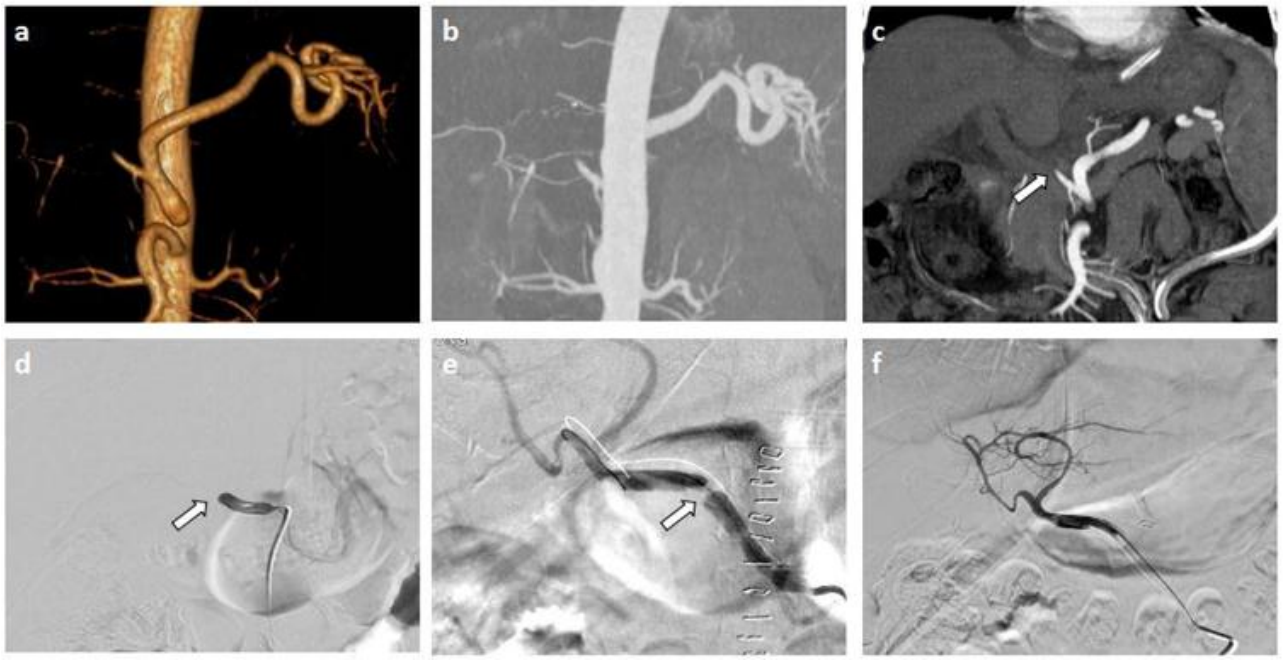

Figure 2: a-f. CDS performed on postoperative day 10 shows an interruption of the hepatic artery. MDCTA -VR (a) and MDCTA-MIP (b, c) performed later shows an interruption of the hepatic artery (c, arrow). Selective hepatic artery angiography confirms the total hepatic artery occlusion after liver transplantation (d, arrow). Thrombolysis performed with an initial bolus injection of urokinase through catheter combined with transcatheter micro-pump continuous infusion of urokinase (50,000U/h) for 48 hours restores hepatic artery flow and underlying anastomotic stenosis is observed, the degree of stenosis is greater than 70% (e, arrow). PTA combined with uncovered stent placement was performed to treat the coexistent anastomotic stenosis. Final selected hepatic arterial angiography shows a good caliber of the anastomosis and good filling of intrahepatic arterial branches (f).

Figure 3

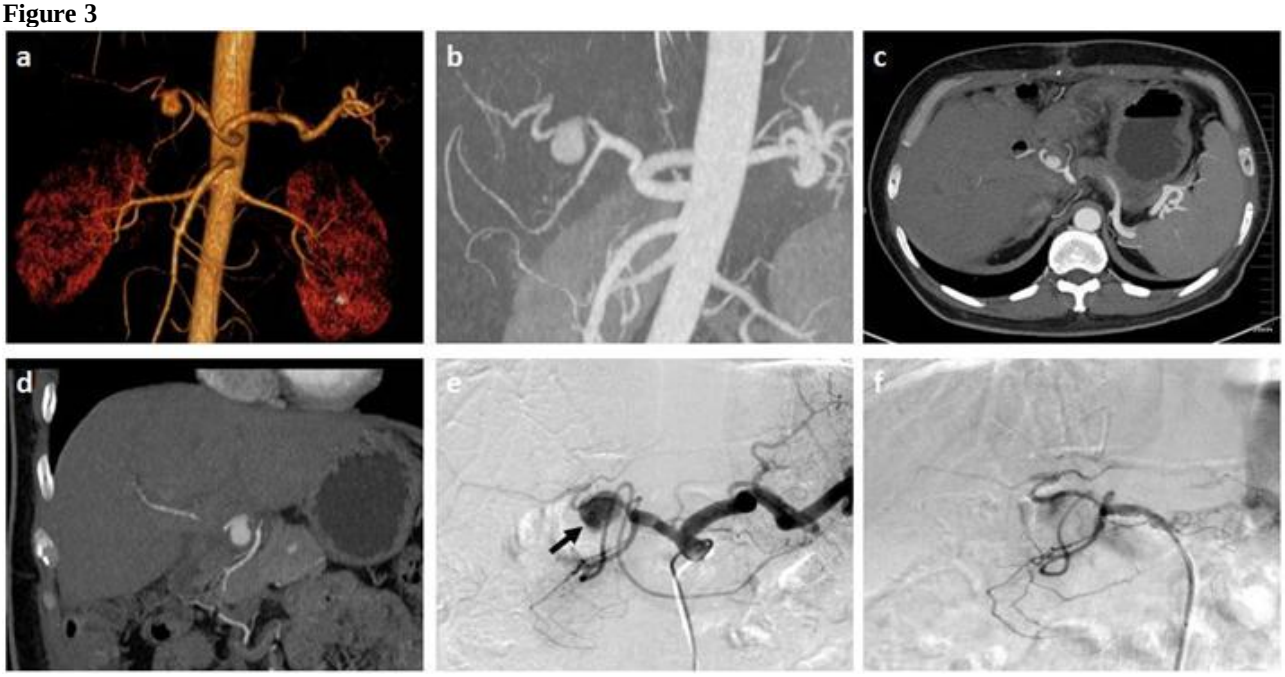

Figure 3: a-f. Routine MDCTA performed on postoperative day 21 shows extrahepatic arterial pseudoaneurysm (a-d). Celiac artery angiography confirms the anastomotic pseudoaneurysm after liver transplantation (e, arrow). Transluminal angioplasty was performed by using a micro-balloon (2mm×1.5mm), then two stent-grafts (4.5mm×30 mm) were placed, overlapping at the artery fistula for 20mm. Angiography re-examination shows obvious occlusion of the hepatic artery anastomotic pseudoaneurysm and patent hepatic arterial flow was observed (f).

DISCUSSION

Hepatic artery complications, including hepatic artery thrombosis, stenosis, bleeding and pseudoaneurysm, are the most common and serious complications after liver transplantation(LT) and the morbidity is 4% to 16%.[7] These complications can lead to high rates of graft loss, morbidity, and mortality. Therefore, it is important for early detection and management to improve graft salvage and the survival rate of patients after LT. Most hepatic artery complications appear within 3 months after LT due to the difficulty of distinguishing their clinical manifestations and laboratory indexes from others, such as graft rejection or dysfunction, intra-abdominal infection and non-vascular complications. As the golden standard for the diagnosis of a variety of vascular lesions, DSA is not usually the first choice due to its invasive characteristic. At this time, imaging tests are necessary for early diagnosis. Abnormal blood vessel changes can be assessed by CDS, multidetector computed tomography (MSCT) and magnetic resonance imaging (MRI) in the early stage after LT, they are also the common and useful methods for follow up. When these conventional examinations cannot reveal the detailed anatomic relationship and characteristic features of hepatic artery lesions, DSA can be performed to confirm the location and characteristics of hepatic artery complications. As a simple and non-invasive method, CDS is the preferred means to dynamically assess the hepatic artery patency of patients post-transplantation. Due to the excellent spatial resolution and fast scan times with multislice scanner, multidetector computed tomographic angiography (MDCTA) gives a rapid, accurate assessment of hepatic arterial anatomy after LT, it is an effective and non-invasive way to depict small vessels. Volume-rendered (VR) images and maximum intensity projection (MIP) from MDCT can further improve the accuracy of the diagnosis of hepatic artery lesions. Therefore, in the current study, we used bedside CDS routinely to detect vascular lesions at the early stage after LT. When abnormal CDS findings were observed, MDCTA examination was performed for all cases as soon as possible and it helped in achieving early diagnosis.

HAT is the most common and severe vascular complication after LT, it often occurs within 10 days after LT, and can also occur in a few years later. As previous study reported,[8] HAT has been divided into two types according to the time of thrombosis after LT: early HAT (within the first 30 days after LT) and late HAT (30 or more days after LT). In our group, the median interval from LT to the occurrence of HAT was 20 days (range：3 days-45 days), including three cases of an early HAT and two cases of a late HAT. The early HAT is associated with operation technique and hepatic artery lesions,[9] it can result in fulminant hepatic necrosis, bile duct ischemia necrosis and uncontrollable sepsis and relatively has a higher mortality than a late HAT. Therefore, since the early HAT is confirmed through angiography, it needs urgent treatment to prevent graft loss. The late HAT is usually caused by ischemic or immune injury. More than 50% of the recipients only showing abnormal liver function, without clinical symptoms.[10,11] For the early HAT, re-transplantation is thought to be the main method to treat it before and this method can obviously improve patients survival rate, but the procedure is very invasive and can have a variety of complications. In the meantime, donors of liver transplantation are limited and it is difficult to get enough for patients need to re-transplantation. Until recently, surgical revascularization has been considered as the first choice to treat HAT in the early stage after and it provides the opportunity to avoid re-transplantation, especially for patients who have significant and severe clinical symptoms and unstable condition within the early period of post-transplantation. Recent years, endovascular interventional treatment has been used to treat HAT and acquired effective results. Abdelaziz et al[12] reviewed the cases of 11 adult patients with the early HAT who underwent thrombolysis after LT. Technical success rate and long-time patency was 82.8% and 66.7%, respectively. 18.2% of the patients were complicated with haemorrhage.

As for thrombolytic therapy, conventional intravenous delivery of thrombolytic agents often has a low success rate in treating hepatic artery thrombosis (HAT) due to a single bolus injection with a large dose of a thrombolytic agent, which can also lead to bleeding. Transcatheter micro-pump continuous infusion of urokinase has been used as a continuous infusion, bolus or combination of both. There is no consensus on the optimal technique for catheter-directed thrombolytic therapy at present. Several studies have demonstrated the clinical safety and efficacy of these strategies to vascular thrombosis with different dosing regimen. Boyvat et al[3] have recommended a dose of 1-3 mg recombinant tissue plasminogen activator (rt-PA) or urokinase (UK) at a dose of 50,000–250,000 IU for complete occlusion thrombus lesions of hepatic arteries. Zhou et al[4] have used up to 9 million units of UK without any complication in one particular patient. The duration of thrombolytic therapy has been reported are variable. Zhou et al[4] have recommended 2-4 days of thrombolytic therapy to accomplish the treatment successfully by using different dosing regimens. However, Other studies have suggested that intra-arterial thrombolysis should be terminated, if there is residual thrombus or persistent HAT after 36-48h of thrombolytic therapy.[5] Due to the short half-life of UK, in the current study, a combination of bolus and continuous infusion of urokinase for catheter-directed thrombolysis was performed to achieve the continuous and full contact between UK and thrombus, so as to make the best of thrombolytic activity of UK. Patency rate achieved in four patients (80%). In one patient with the totally occluded hepatic artery, CDT was failed due to the long-time formation of thrombus. This study further demonstrated the significance of CDT for treatment of HAT. However, once the dissolution of thrombus was still poor by means of thrombolysis for five consecutive

days, it should be considered as tumor thrombus or chronic thrombus. Surgical embolectomy should be performed as soon as possible.

Generally, catheter-directed thrombolysis (CDT) is contraindicated for early HAT (within 2 weeks after LT), the most common complication is bleeding. However, considering the possible result of graft loss, CDT was performed in our group for patients with the early HAT. During treatment procedure, the serum fibrinogen level, prothrombin time (PT) and activated partial thromboplastin time (APTT) were monitored during catheter-directed thrombolysis. CDT was successful in three cases without any complications. Hemorrhage was observed in one patient during CDT and was successfully treated through comprehensive conservative therapy.

Hepatic artery stenosis (HAS) is the second most frequent vascular complication and often occurs within the first three months after LT. HAS is mainly associated with vascular clamp injury, rejection and caliber differences between donor and recipient artery.[13] Hepatic artery stenosis is classified into two types depending on the lesion location which are anastomotic stenosis and non-anastomotic stenosis. Anastomotic stenosis generally related to surgical technique and often occurs within the first three months after LT. A few studies show that HAS has been speculated to progress to HAT.[5,14,16] Saad et al[5] found that untreated HAS has a high rate (65%) to progress to HAT at 6 months after LT. It is easy to understand that HAS resulted in the slow or static blood flow and then causes thrombosis, leading to hepatic necrosis and biliary complications. Therefore, immediate treatment is required to prevent lesion progression. In this study, three cases were found underlying anastomotic stenosis after successful patency through CDT, which further support the perspective that underlying hepatic artery anastomotic stenosis may arise the development of HAT.

Once confirmed, proper treatment should be performed according to the degree of HAS and whether the graft liver dysfunction has been induced. For cases with a degree of stenosis less than 50% and without clinical manifestation can temporarily not be treated. However, routine CDS and laboratory examination should be conducted to dynamically and closely observe the patient's clinical condition. Prompt treatment should be given if progressive liver damage, liver necrosis, biliary leakage or bile duct stricture were observed. With regard to cases with a degree of stenosis is greater than 50%, the operation should be carried out as soon as possible to prevent graft loss. Treatment for HAS including surgical revascularization and endovascular interventional therapy.

Recently years, PTA and stent placement have been used to treat HAS and acquired significant technical success rate and long-term results.[17,18] It is generally acknowledged that PTA is the first choice for patients with HAS. However, PTA alone often requires a repeated treatment. Therefore, in our study, PTA combined with selected stent placement was performed to improve the hepatic artery patency. Complications associated with PTA occur in 5% to 10% patients after endovascular treatment. Hepatic artery anastomotic rupture is a relatively common complication during angioplasty, which can lead to hemorrhage during PTA. Graft-covered stent placement should be prepared to prevent hemorrhage during the procedure, especially at the early stage post-transplantation. The hepatic artery has not been healed in the early period post LT, it is easy to damage the artery anastomosis during PTA. Therefore, in the current study, early HAS (within 2 weeks after LT) were not treated with PTA temporarily to prevent the risk of anastomotic bleeding, rupture, pseudoaneurysm or thrombosis during PTA. Anticoagulant therapy, including an infusion of heparin and/or antiplatelet agents, was adopted until 3 weeks after the diagnose of HAS, then PTA was performed. Late anastomotic stenosis of hepatic artery can be treated with PTA once confirmed. This study demonstrated that our strategy was technically feasible and effective, only one patient was complicated with rupture and was successfully treated with a graft-covered stent.

Hepatic artery pseudoaneurysm (HAP) is a rare complication in patients after LT.[19] The incidence of HAP is less than 3%, and it most often located at the anastomosis and occurs in the early period post LT. HAP has been classified into two types depending on the lesion location which are intrahepatic pseudoaneurysms and extrahepatic pseudoaneurysms. Intrahepatic pseudoaneurysms are most often related to prior, pre-transplantation liver procedures, such as biopsies or transhepaticbiliarydrainage. Extrahepatic pseudoaneurysm are usually associated with the transplantation procedure. HAP can lead to rupture, bleeding, adhesion, and communication with bowel, resulting in infection and sepsis.[20,21]

Massive haemorrhage caused by HAP was mainly treated by surgical operation previously. However, surgical procedures are unacceptable for patients who just underwent LT due to the operation trauma. Selective embolization of the hepatic artery aneurysms lumen can easily lead to the hepatic artery occlusion. Endovascular repair with a graft-covered stent can absolutely isolate the parental artery from aneurysm lumen. As a result, the pressure of aneurysm lumen is reduced and the blood flow stops, which can arise the intraluminal thrombus and occlusion of the aneurysms. In the meantime, the hepatic artery blood flow can keep patent to avoid fatal liver necrosis. The strategy in our study is an effective method to treat HAP, but there is no large cohort study about the efficacy and technique success rate was reported.[22] This study also has some defects like only two patients complicated with extrahepatic anastomotic pseudoaneurysms were included in our group. The pseudoaneurysms were found incidentally by routine

follow-up CT examination. One patient was successfully treated by the graft-covered stent, indicating that endovascular treatment can be a choice for patients with pseudoaneurysms.

The present study has several limitations. First, this is a retrospective study and the sample size is small, especially for patients with pseudoaneurysms. Therefore, the technique success rate cannot be generalized, further research is needed to achieve a more accurate result. Second, this study only paid attention to short and medium-term efficacy. Long-term efficacy requires further follow up.

CONCLUSION

In conclusion, endovascular interventional therapy, including catheter-directed thrombolysis (CDT), percutaneous transluminal angioplasty (PTA) and stent placement, is a relatively safe, effective and feasible method for hepatic artery complications after liver transplantation (LT). Therefore, it can be the first choice for selected patients. Long-term follow-up and further accumulation of cases are needed to confirm these promising initial results.

Conflict of interest disclosure

The authors declared no conflicts of the disclosure.

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