Transpl Int (2004) 17: 163–168
DOI 10.1007/s00147-004-0701-z

ORIGINAL ARTICLE

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Arterial conduits for hepatic artery revascularisation in adult liver transplantation

Received: 18 June 2002
Revised: 3 September 2003
Accepted: 11 March 2004
Published online: 24 April 2004

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Abstract Arterial complications after orthotopic liver transplantation (OLT), including hepatic artery thrombosis (HAT), are important causes of early graft failure. The use of an arterial conduit is an accepted alternative to the utilisation of native recipient hepatic artery for specific indications. This study aims to determine the efficacy of arterial conduits and the outcome in OLT. We retrospectively reviewed 1,575 cadaveric adult OLTs and identified those in which an arterial conduit was used for hepatic revascularisation. Data on the primary disease, indication for using arterial conduit, type of vascular graft, operative technique and outcome were obtained. Thirty-six (2.3%) patients underwent OLT in which arterial conduits were used for hepatic artery (HA) revascularisation. Six of these were performed on the primary transplant, while the rest ($n = 30$) were performed in patients undergoing re-transplantation, including six who had developed hepatic artery aneurysms. The incidence of arterial conduits was 0.4% (6/1,426 cases) in all primary OLTs and 20.1% (30/149 cases) in all re-transplants. Twenty-nine procedures utilised iliac artery grafts from the same donor as the liver, six used iliac artery grafts from a different donor, and a single patient underwent a polytetrafluoroethylene (PTFE) graft. Two techniques were used: infra-renal aorto-hepatic artery conduit and interposition between the donor and recipient native HAs, or branches of the HAs. The 30-day mortality rate for operations using an arterial conduit was 30.6%. Three conduits thrombosed at 9, 25 and 155 months, respectively, but one liver graft survived without re-transplantation. The arterial conduits had 1- and 5-year patency rates of 88.5% and 80.8%. The 1- and 5-year patient survival rates were 66.7% and 44%. We can thus conclude that an arterial conduit is a viable alternative option for hepatic revascularisation in both primary and re-transplantation. Despite a lower patency rate than that of native HA in the primary OLT group, the outcomes of arterial conduit patency and patient survival rates are both acceptable at 1 and 5 years, especially in the much larger re-OLT group.

Keywords Orthotopic liver transplantation · Arterial conduits · Hepatic artery thrombosis

Introduction

Orthotopic liver transplantation (OLT) is an accepted form of treatment for end-stage liver disease and has a proven long-term outcome [1, 2]. Hepatic artery thrombosis (HAT) is one of the most common causes of early graft failure and usually requires re-OLT [3, 4]. The reported incidence of HAT is between 2.7% and 8% [5, 6]

in adults and 1.7% and 11% in children [4, 7, 8]. Several strategies have been introduced to decrease the incidence of HAT, such as avoiding the known risk factors predisposing to HAT [7, 9], and using improved techniques of graft preservation [10] and microsurgical techniques [11, 12, 13]. Regular scanning of the hepatic artery (HA) with the colour duplex scan can detect HA stenosis before complete HA occlusion, and HA stenosis can be successfully treated with angioplasty [14]. Careful monitoring for HAT and early intervention can be effective in patients with HAT after OLT [8, 15, 16, 17, 18].

The use of an arterial conduit is an alternative technique for hepatic artery revascularisation during OLT that can be utilised if there is inadequate length of donor or recipient HA or if the recipient HA is unsuitable in both primary OLT and re-OLT [19]. An arterial conduit can also be used if a complication of the HA occurs, i.e. HA stenosis [6] or HA aneurysm [20]. Several techniques of HA conduits have been reported, including arterial or venous grafts and suprarenal, infra-renal aortic conduits or interposition grafts [17, 19, 20]. There have been few reports of the long-term patency of arterial conduits and the outcome of OLT in grafts revascularised using HA conduits [19, 21, 22]. This study reports on the efficacy of arterial conduits and on the graft and patient outcome using the donor iliac artery for hepatic revascularisation in primary OLT and re-OLT and reconstruction of the HA following a HA complication after OLT.

Materials and methods

Data on recipient selection, donor organs, operative factors, postoperative management and follow up were collected by a data manager not involved in the clinical management of the donors or recipients. The data was stored on databases developed initially using dBase (Ashton Tate) and more recently Chameleon Infoflex software (Chameleon Information Management Systems). Routine preoperative imaging studies in recipients comprised colour duplex scan, abdominal computed tomography (CT) scan, or abdominal magnetic resonance (MRI) where indicated. Hepatic artery angiography was performed in selected cases where re-OLT was considered secondary to HAT.

Donor iliac arteries and veins were routinely harvested after retrieving the liver graft and preserved in a UW solution at 4C. A conventional OLT with veno-venous bypass was used in the majority of cases. Hepatic artery revascularisation was routinely performed as an end-to-end anastomosis between the donor and the recipient native HA or a branch of the donor celiac trunk. An arterial conduit for hepatic artery revascularisation was used in certain recipients: if the flow from the recipient HA was insufficient (assessed clinically), if the HA (donor or recipient) was too short, or if a recipient HA was not easily identified. An arterial conduit was also used to reconstruct the HA if complications occurred after OLT (e.g. stenosis, thrombosis, aneurysm or pseudoaneurysm). An interposition conduit was used if the donor vessel was too short to reach the chosen recipient vessel (e.g. coeliac axis), and an infra-renal conduit was used if the in flow was deemed insufficient. A cyclosporine-based (until 1999) or tacrolimus-based (from January 2000) triple immunosuppressive protocol with azathioprine and tapering prednisolone was adopted during the postoperative period.

Patients who underwent OLT using an arterial conduit for hepatic revascularisation were identified from the liver unit database. Clinical information on primary disease, indication for using an arterial conduit, type of vascular graft, operative technique and outcome were then obtained from the patients' records and the prospective database.

Results

Between 1982 and March 2001, a total of 1,575 adult cadaveric OLTs were performed at the Liver Unit, Queen Elizabeth Hospital, Birmingham, UK. Of these, 1,535 were whole organ, 35 were split and five were cut-down OLTs. There were 1,426 primary OLTs and 149 re-OLTs. An arterial conduit was used in 36 (2.3%) OLTs for hepatic artery revascularisation, all of which were whole organ transplants. The incidence of HA conduits was 0.4% (6/1,426 cases) among all patients undergoing primary OLT and 20.1% (30/149 cases) in patients undergoing re-OLT. No patients received anticoagulants after OLT and aspirin (75 mg/day) was prescribed in a single patient for symptoms related to coronary artery disease in the postoperative period.

The patient demographics and underlying liver disease can be seen in Table 1. The median age of these patients was 49 years (25–62 years). Six (16.7%) arterial conduits were used in primary OLTs due to unsuitable recipient HAs (four because of small recipient HAs, one because of poor arterial flow and one because of adhesions from a previous hepaticojejunostomy). A total of 24 (66.7%) conduits was used in re-OLTs, 18 of these conduits (17 patients) were secondary to HAT in a previous OLTs. The remaining six (16.7%) conduits were used to reconstruct the HA without immediate recourse to re-OLT (three because of inadequate length of recipient HA, two due to dense adhesions in a third re-OLT and one because of poor arterial flow). Of the 18 OLTs performed for HAT, liver failure developed in seven cases, and biliary sepsis (cholangitis associated to biliary stricture and/or liver abscess) occurred in all the rest. One patient required an arterial conduit for their primary OLT and had a re-OLT following HAT in their primary graft. Of the 36 conduits, six were used for HA

Table 1 Demographic data of the liver transplant patients using arterial conduit for hepatic artery revascularisation

Primary disease	Number	Gender (Male/female)	Indication for arterial conduit			
			Primary OLT	Re-OLT HAT	Re-OLT non-HAT	HA complication
Chronic liver disease						
Primary sclerosing cholangitis	8	7/1	1	4	1	2
Autoimmune hepatitis	8	3/5	3	3	2	–
Primary biliary cirrhosis	7	1/6	–	5	–	2
Cryptogenic cirrhosis	3	2/1	2	2	–	–
HCV cirrhosis	1	1/0	–	–	1	–
Alcoholic cirrhosis and HCC	1	1/0	1	–	–	–
Metabolic cirrhosis	1	1/0	–	1	–	–
Acute liver failure						
Paracetamol overdose	2	0/2	–	2	–	–
Non-A non-B hepatitis	4	2/2	–	1	2	2
Total	35	18/17	6	18	6	6

reconstruction secondary to HA aneurysms occurring after re-OLT (four infected and two non-infected HA aneurysms).

In these 36 operations, three types of vascular grafts were used; in 29 cases, (80.6%) iliac arteries from the same donor, in six cases iliac arteries from a different donor and in one case a polytetrafluoroethylene (PTFE) graft were used for the conduit.

We interposed 31 (86.1%) arterial conduits (30 iliac artery grafts and one PTFE graft) between the recipient infra-renal aorta and the HA from the donor liver. In the other five cases the grafts were interposed between the donor and recipient native HAs (Table 2). All infra-renal aortic conduits were brought to the lesser sac through the transverse mesocolon behind the stomach and in front of the pancreas as described by Tzakis et al. [23]. None of the conduits were interposed from the recipient suprarenal aorta.

The outcome in the 35 patients having hepatic vascularisation using 36 HA conduits have been categorised into the following three groups (Table 2).

Group 1

Of the 36 OLTs performed in this study, 11 (30.6%) resulted in perioperative deaths. These were due to massive bleeding unrelated to their vascular conduit [3], multiple organ failure [3], sepsis [3], liver failure [1] and severe acute rejection [1]. The vascular conduit in nine cases was an iliac artery from the same donor (one in a primary OLT and eight in re-OLTs). An iliac artery

Table 2 Types of arterial conduits and their outcomes in each group. *CA* coeliac artery, *CHA* common hepatic artery, *GDA* gastroduodenal artery, *SM* superior mesenteric artery, *s-IA* iliac artery from the same donor, *d-IA* iliac artery from different donor, *Number in parentheses* number of arterial conduits

Revascularisation technique	Number	Type of conduit	Group 1	Group 2	Group 3	
					Good LFT	Lost graft
Interposition graft (donor–recipient)						
CA–CHA	2	s-IA(1), d-IA(1)	d-IA(1)		s-IA(1)	
CHA–CHA	2	d-IA(2)		d-IA(1)	d-IA(1)	
CHA–Splenic A	1	s-IA(1)	s-IA(1)			
Aortic conduit (donor–recipient)						
Aortic patch–aorta	2	s-IA (2)			s-IA (2)	
CA stem–aorta	16	s-IA(14), d-IA(1), PTFE(1)	s-IA (2). d-IA(1)	s-IA (1)	s-IA(9)	s-IA(2) PTFE(1)
GDA bifurcation–aorta	2	s-IA (2)	s-IA (1)	s-IA (1)		
CHA stem–aorta	7	s-IA (6), d-IA(1)	s-IA(3)		s-IA (2) d-IA(1)	
Splenic patch–aorta	3	s-IA(2), d-IA (1)			s-IA (1)	s-IA (1) d-IA (1)
SMA–aorta	1	s-IA(1)	s-IA (1)			
Total	36	s-IA (29), d-IA (6), PTFE(1)	s-IA(9), d-IA(2)	s-IA(2), d-IA(1)	s-IA(15), d-IA(2)	s-IA(3), d-IA(1), PTFE(1)

from a different donor was used for reconstruction of a HA aneurysm in two cases.

Group 2

Three (8.3%) conduits in three patients thrombosed after OLT (one in a primary OLT, one in a re-OLT and one in a HA aneurysm) at 9, 25 and 155 months post OLT. The vascular conduit in two patients was an iliac artery from the same donor. One of these patients lost their graft and died 9 months after OLT while the other developed thrombosis of the arterial conduit 25 months after OLT. The latter was transferred to group 3 after re-transplantation using an arterial conduit. In the third patient, an iliac artery from a separate donor was used for HA reconstruction. The patient is alive with good liver function despite re-thrombosis of the arterial conduit 13 years after OLT.

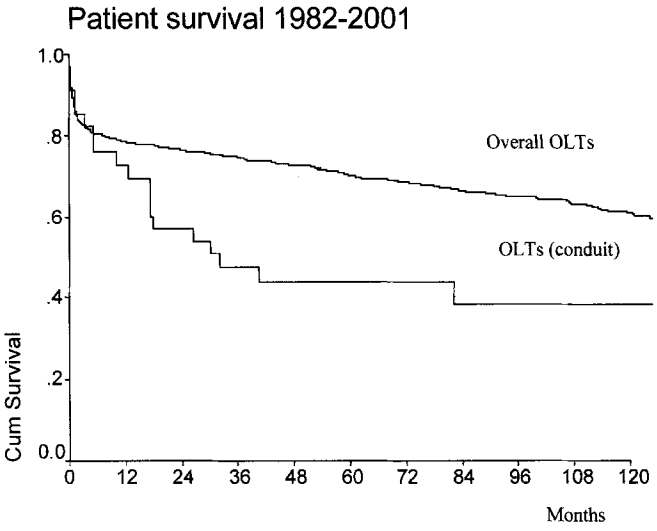

Fig. 1 The outcome of overall adult liver transplantation and OLTs using arterial conduits for hepatic artery revascularization between 1982 and 2001

Group 3

No thrombosis of the arterial conduit occurred in 22 patients, although 5 patients died with a patent conduit, with median follow up of 46 months (range 1–155) after HA revascularisation.

Seventeen patients (47.2%) including one patient from group 2 are alive with normal liver function. In 15 of these patients, iliac arteries from the same donor were used and in two the iliac artery from a different donor was used (Table 2). Of 22 patients, five lost their liver while the arterial conduits (three from the same donor, one from different donor and one of PTFE) are still patent (Table 2). The non-surviving livers resulted from an operative death in two cases (intra-abdominal sepsis) and unrelated conditions in three cases (one sepsis, one pneumonia and one haemothorax).

The patency rates of arterial conduits at 1 and 5 years in our series are 88.5% and 80.8%, respectively (median 46 months, range 1–155 months). The median survival of patients requiring vascular conduits during OLT is 46 months (1–178 months). Nine patients are long-term survivors with survival rates over 8 years. The overall patient survival rates in our series using arterial conduits at 1 and 5 years are 73% and 44%, respectively (Fig. 1), while the 1- and 5-year survival rates of the overall adult OLTs in the same period are 81% and 73% respectively (Fig. 1).

In the same period as this study there were 58 cases (54 primary OLTs and 4 re-OLTs) of thrombosis of the native HA occurring in 55 of 1,439 patients (3.8% patients and 4.0% OLTs) who had their native HAs used for OLTs. Of the 55 patients, 39 underwent re-transplantation. Eighteen (31%) cases required arterial conduits for the re-OLTs and were included in this study; 21 cases (36.2%) had their native HAs used for re-OLTs, eight (14.5%) remain well without re-OLT, five (9%) died and two (3.6%) had attempted revascularisation but ultimately underwent re-OLT. The outcome of re-OLTs using the native HAs was good in 14 cases (66.67%), a perioperative death occurred in four cases (19.1%), a further patient died of other causes and in two a further HAT occurred (11.76%). The incidence of HAT in primary OLTs using native arteries and arterial conduits was 54/1,426 (3.8%) and 1/6 (16.7%) respectively (Table 3 and group 2). In re-OLTs the incidence of HAT was 3.2% (4/125) and 4.2% (1/24) in cases using native arteries and arterial conduits for hepatic artery revascularisation respectively (Table 3 and group 2). When all cases of primary OLTs and re-OLTs were considered together, the incidence of HAT was twice that in cases using arterial conduit than using native hepatic artery (6.7 vs 3.7%) (Table 3).

Table 3 Incidence of HAT after OLTs using native HAs and arterial conduits for revascularisation

Type of OLT	Number of HAT	
	OLTs using native HA ($n=58$)	OLTs using arterial conduits ($n=30$)
Primary OLT ($n=1,426$)	54/1,420 (3.8%)	1/6 (16.7%)
Re-OLTs ($n=149$)	4/125 (3.2%)	1/24 (4.2%)
Total	58/1,545 (3.75%)	2/30 (6.7%)

Discussion

This study reports the incidence of arterial conduit for HA revascularisation in a series of 1,575 adult OLTs. The reported incidence of arterial conduits in adult OLTs varies from 11 to 32% [19, 21, 22]. In our series the incidence of arterial conduits was only 2.3%. None of the cut-down or split liver OLTs in our series required arterial conduits for vascular reconstruction. Donor iliac artery was most frequently used for arterial revascularisation in our own series and this was usually from the same donor as the hepatic graft, as with other series reported in both children and adults [19, 21, 22].

In the other reported series of adult OLTs, arterial conduits were mainly used in patients undergoing primary OLT (30–65%) [19, 21, 22] whereas in our study only 16.7% of the patients were undergoing primary transplantation, suggesting that our own use of arterial conduits in patients undergoing primary OLT is low. Despite this donor, iliac arteries should be routinely procured after retrieving the liver graft because of the risk of the unexpected unsuitable recipient HA and because they may occasionally be required to reconstruct the HA if a complication occurs after transplantation. These vascular conduits can be preserved for 14 to 30 days and still provide the same patency rate as a fresh homograft [24].

The OLTs that required an arterial conduit in our study were associated with a high operative mortality rate (30%) because in most cases (30/36 operations) they were performed for high-risk recipients (Table 1). Those patients undergoing re-OLT for HAT usually had liver failure or biliary infection and those patients undergoing emergency reconstruction were haemodynamically unstable because of infected or ruptured HA aneurysms.

The reported incidence of thrombosis of arterial conduits varies. One series reported a similar incidence of HAT in primary OLTs using arterial conduits or native HAs, but an increased incidence of HAT in re-OLTs using arterial conduit [22]. Another series reported a higher incidence of HAT in both primary OLTs and re-OLTs using arterial conduits than in OLTs using native arteries [19]. The incidence of HAT in OLTs using an arterial conduit is nearly 5 times higher than in OLT using native HAs in primary OLT (16.7% vs 3.8%) but is only slightly higher in re-OLT (4.2% vs 3.2%) (Table 3). Although there is a higher incidence of thrombosis in arterial conduits compared to the native HA, the outcome of arterial conduits for reconstruction of the HA is reassuring. The patency rate is high (88.5% at 1-year and 80.8% at 5-years) and is similar to the rate reported in other studies [19, 21, 22].

The numbers of different types of arterial conduits (allograft from the same donor, different donor and PTFE) are small and therefore we could not demonstrate a difference in patency rates. After excluding those patients dying in the perioperative period, three out of four arterial conduits (Table 2) from a different donor remain patent; this is consistent with results in other reported series [24].

Interposition grafts and infra-renal aortic conduits were effective for revascularisation of the HA but because of the small numbers, no difference could be found between the two types of reconstruction. Currently, the two types of reconstruction have not been compared. The perceived advantages of an aortic conduit are a high flow and a virgin area for anastomosis, whereas the interposition graft requires a shorter artery that is potentially at a lower risk of thrombosis.

Immediate re-transplantation is usually required in symptomatic early HAT. In this study all arterial conduit thromboses occurred late (9, 20, 155 months) after transplantation; one patient had time to wait for a new liver and the other liver graft functioned well without re-OLT. This suggests that despite a higher risk of thrombosis, the advantage of arterial conduits is that the liver graft might have time to develop a collateral circulation and survive in cases of late onset HAT. This is supported by another study that suggested that half of the patients with a late HAT survive without re-transplantation [15].

Most patients that required an arterial conduit survived more than 48 months and several survived for longer than 8 years. Although the patency rate of arterial conduits is encouraging, it is inferior to the native HAs for revascularisation in OLT, which provides lower incidence of HAT (Table 3).

Although several strategies have been introduced to prevent HAT after liver transplantation, there are still some unpredictable or unidentified factors that lead to HAT. The incidence of thrombophilic conditions in our series is unknown, but recent changes in practice have lead to a more aggressive approach in screening for these conditions especially in patients with recurrent HAT. We have not routinely used anti-platelet therapy in our patients but the available evidence suggests that this might not have an effect on HAT in OLT [25]. In our own series the use of vascular conduits is lower than reported elsewhere but this is clearly not at the expense of rates of HAT. The outcome of arterial conduits and the liver graft are encouraging at 1 and 5 years and an arterial conduit can therefore be considered as an alternative for hepatic revascularisation in both primary and re-OLT. Despite a lower patency rate than native HA in the smaller primary OLT group, the outcomes of arterial conduit patency are comparable in the much larger re-OLT group. The iliac vessels should be routinely procured after retrieving the liver graft because they offer the most useful type of conduit for hepatic revascularisation when native HAs cannot be used or for HA complications after OLT.

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