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Impact of Variant Donor Hepatic Arterial Anatomy on Clinical Graft Outcomes in Liver Transplantation

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Introduction

Standard hepatic arterial anatomy is composed of the common hepatic artery proceeding from the celiac trunk and giving rise to the gastroduodenal artery (GDA) and proper hepatic arteries. Reconstruction of the hepatic arterial supply during liver transplantation, often complex in nature, can be required in cases of accessory or replaced vessels. A recent review summarized the hepatic arterial anatomy reported in over 19,000 cases from 20 individual studies. (1)

It has been suggested that the presence of nonstandard donor arterial anatomy may be related to an increased incidence of hepatic artery thrombosis (HAT).(2) Although the overall incidence of HAT is low, it can have devastating effects, including the need for retransplantation, long-term biliary complications, and increased patient mortality. This article describes the arterial anatomy in a large number of liver transplants, with routine anastomosis of a very short hepatic artery and routine reconstruction of the accessory right hepatic artery to the GDA. Study outcomes include incidence of HAT within 30 days of transplant, early graft loss up to 1 year after transplant, and 10-year graft survival.

Patients and Methods

This study reviews all deceased donor orthotopic liver transplants at a single center (2007 to 2017). A retrospective analysis of data for liver transplant patients at our center was reviewed and approved by the institutional review board of the Indiana University School of Medicine. Donor anatomy was classified into 1 of 6 types: type 1, standard anatomy; type 2, accessory/ replaced left hepatic artery from the left gastric artery (LGA); type 3, accessory/ replaced right hepatic artery from the superior mesenteric artery (SMA); type 4, combination left and right accessory/replaced hepatic arteries; type 5, completely replaced hepatic artery with origin from the SMA; and type 6, other variants. The determination between a replaced and an accessory vessel is not always required because the intrahepatic branches of the main hepatic artery are not routinely dissected, and these variants are considered equivalent for this study. (3)

All accessory/replaced right hepatic arteries were reconstructed to the GDA over a 5-Fr pediatric feeding tube with a continuous 7–0 Prolene suture on the back table. This reconstruction was first described by Merhav et al. as a salvage technique for failed reconstruction to the splenic artery.(4) Nearly all accessory/replaced left hepatic arteries were left intact from their origin at the LGA and hepatic artery when possible, though occasional reconstruction to the GDA with a 7–0 Prolene suture was performed. Other complex reconstructions were occasionally required secondary to procurement injuries, kinking, or redundancy in the main hepatic artery, and early bifurcation of the main hepatic artery. The vascular anastomosis was sewn in a direct end-to end configuration without beveling of either side. The length of both the reconstructed vessels and the main hepatic artery was always kept to an absolute minimum to avoid vessel redundancy. This approach supposes that excess length results in kinking of the vessel, turbulence of flow, and possible thrombosis. The described technique was used by all surgeons who operated on patients in this cohort, and this same technique was taught to all fellows during this time period. In short, this technique was developed by 1 surgeon (the program director) and was practiced by all subsequent surgeons to ensure quality and consistency.

Because the primary arterial anastomosis is formed near the donor GDA in nearly all cases, the presence of an arterial injury during procurement rarely impacted the anastomosis. No patients received short-term or long-term anticoagulation as a result of arterial reconstruction. Anticoagulation was only used in cases of HAT or in patients with a known hypercoagulable defect. Aspirin (325 mg) once daily was routinely prescribed for all patients and continued for the first year after transplant.

Antithrombolytic therapy was administered routinely at the beginning of every liver transplant case (aprotinin, epsilon aminocaproic acid, or tranexamic acid). A single Doppler ultrasound (US) was obtained per protocol within 12 hours of transplant to confirm flow. No other imaging (intraoperative or postoperative) was obtained without indication. Inadequate flow through the anastomosed hepatic artery by Doppler US prompted immediate return to the operating room for hepatic artery evaluation and/or revision.

Results

There were 1145 transplants included in this analysis. The majority of transplant recipients in this cohort were white and male, with a median age of 57 years and body mass index of 28.4 kg/m2. Median Model for End-Stage Liver Disease (MELD) score at transplant was 20, with 4% of cases being a retransplant (Table 1).

A total of 68% of the livers had a standard anatomy, with the accessory/replaced left (16%) and right (10%) arteries being the most common variants. There were 50 (4%) cases of combined right and left accessory/replaced hepatic arteries. The least common categorized variant in the cohort was a completely replaced hepatic artery from the SMA (<1%). There were 16 patients with other aberrant anatomy. Back-table arterial reconstruction was required in 222 (19%) of the transplant procedures. In all liver grafts with an accessory right hepatic artery (right only or right and left both), there was reconstruction of the accessory/replaced right artery to the GDA (n = 161 total). The remaining 61 reconstructions were variable, though the majority consisted of an anastomosis of the accessory/replaced left hepatic artery to the GDA. The next most common reconstruction was the repair of an artery injured during procurement (Table 1).

There were 15 patients with documented HAT (1%). The incidence of HAT was not significantly higher in recipients receiving a graft that had nonstandard donor anatomy or for those that underwent back-table arterial reconstruction, when compared with grafts with standard anatomy and no reconstruction. Overall 1-year graft survival for all anatomy types was 86%. Graft survival at 1 year did not significantly differ between grafts undergoing arterial reconstruction and those that did not (Table 2).

In total, there were 23 patients with graft loss within 7 days after liver transplant. Among these, 13 patients had a graft with type 1 anatomy, 4 had type 2 anatomy, 4 had type 3 anatomy, and 2 had type 4 anatomy. HAT was a rare cause of early graft loss (2/23, 9%). More commonly, the grafts were lost to primary graft non-function (5/23, 22%) or death from perioperative complications with normal graft function (16/23, 69%).

Cox regression multivariate analyses (not shown) were used to evaluate graft survival up to 10 years after transplant based on graft anatomy type as well as arterial reconstruction status. Overall, there was no significant difference demonstrated in 10-year graft survival between the varying types of hepatic artery anatomy. When comparing grafts undergoing any arterial reconstruction versus all others, there is no statistical difference in 10-year graft survival ($P = 0.54$).

Discussion

This manuscript describes a unique population in which (1) the hepatic artery length was minimized in all patients and (2) the accessory/replaced right hepatic artery was always reconstructed to the GDA to maintain this short length throughout. This approach resulted in a HAT rate of 1% with excellent long-term survival and without any use of anticoagulation. Often, the donor hepatic artery is manipulated during procurement, which may result in unrecognized traction or intimal injury. Anastomosis of the donor hepatic artery at the level of the GDA, or between the GDA and the liver, generally uses an untouched segment of the artery to minimize this risk. In this series, the accessory right hepatic artery was always reconstructed to the GDA. When procured simultaneously with the pancreas, this short GDA reconstruction allows the accessory right artery to be transected distal to its passage through the pancreas, leaving the intra-pancreatic portion intact and avoiding sacrifice of the proximal portion of the SMA. Routine use of this technique, then, would result in fewer pancreas grafts being sacrificed.

When compared with other published reports of variant hepatic arterial anatomy, this cohort demonstrated comparable rates of normal “textbook” standard anatomy as well as accessory/replaced vessels. Previous anatomical studies have found the normal type 1 anatomy pattern to be present in 54%−79% of patients. (1,3,5) Type 2 and type 3 anatomy have been widely reported as the next most common anatomical patterns, ranging from an incidence of 7%−13% and 6%−15%, respectively. Of these most common anatomic variants, the type 3 anatomy with an accessory/replaced RHA is of most interest because this always requires an arterial reconstruction during the back-table preparation of the graft.

The overall incidence of early HAT within 30 days of transplant in this cohort was 1%. In the present study, there was a higher rate of HAT in grafts with arterial reconstruction when compared with grafts without reconstruction (2% versus 1%), but this did not reach statistical significance (P = 0.16). These grafts with arterial reconstruction had an equivalent Doppler US profile and 1-year graft survival but a higher risk of 7-day graft loss (4% versus 2%; P = 0.02). The exact cause of HAT is not always known and is likely multifactorial. Back-table reconstruction of the hepatic vessels has certainly been considered a risk factor for HAT. In addition to back-table reconstruction, many other risk factors for HAT have been reported including pediatric organs with smaller arteries, those undergoing aortohepatic grafting, and a history of transarterial chemoembolization. (5)

In conclusion, a wide variety of complex arterial presentations can be successfully transplanted with excellent long-term results. This study presents a consistent method of arterial reconstruction over a period of 10 years' time in which the arterial length was always kept to a minimum and reconstruction to the GDA was consistently employed. Certainly, other reconstruction techniques may be equally effective, though the most important factor is likely the consistent use of a single technique in which the individual surgeon can become proficient with reproducible results.

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Table 1.

Demographic data for 1145 liver transplant recipients over a 10-year time period with summary of arterial anatomic variants.

	All patients
Overall	1145
Gender	
Male	67%
Race	
White	88%
Black	6%
Other	6%
Age (years) *	57
Body mass index *	28.4
MELD at transplant *	20
Retransplant	4%
Diagnosis	
Hepatitis C	33%
Hepatocellular carcinoma	24%
Alcoholic liver disease	29%
Fatty liver disease	20%
Tobacco use	
Never smoker	54%
Ever smoker	46%
Hepatic arterial anatomy variants	
Standard anatomy	780 (68%)
Accessory/replaced left	180 (16%)
Accessory/replaced right	111 (10%)
Accessory right and left arteries	50 (4%)
Completely replaced superior mesenteric artery	8 (1%)
Other variant	16 (1%)
Any back table arterial reconstruction	222 (19%)

*Median value

Table 2.

Clinical outcomes for arterial anatomic variants (n=1145)

	Number	Hepatic artery thrombosis (HAT) (30-day)		Initial resistance index by doppler ultrasound* Main hepatic artery		Right hepatic artery		Left hepatic artery		Graft loss within 7 days		1-year graft survival	
		15 (1%)		0.74		0.68		0.65		23 (2%)		86%	
Hepatic arterial anatomy variants													
Standard anatomy	780 (68%)	9 (1%)		0.74		0.69		0.66		13 (2%)		86%	
Accessory/replaced left	180 (16%)	3 (2%)		0.76		0.70		0.64		4 (2%)		83%	
Accessory/replaced right	111 (10%)	1 (1%)		0.71		0.66		0.66		4 (4%)		84%	
Accessory right and left arteries	50 (4%)	2 (4%)		0.71		0.65		0.62		2 (4%)		92%	
Completely replaced artery	8 (1%)	0 (0%)		0.82		0.75		0.72		0 (0%)		100%	
Other variant	16 (1%)	0 (0%)		0.61		0.60		0.53		0 (0%)		88%	
Any back table reconstruction	222 (19%)	5 (2%)	p=0.16	0.71	p=0.40	0.67	p=0.20	0.63	p=0.18	9 (4%)	p=0.02	84%	p=0.27
No back table reconstruction	923 (81%)	10 (1%)		0.74		0.69		0.66		14 (2%)		87%	

* median value