

Anatomical variations of the hepatic artery in liver grafts from brain-dead donors

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Abstract

Introduction: The anatomical variations of the hepatic artery are a critical consideration in liver transplantation, impacting both surgical planning and postoperative outcomes. This study aimed to identify and classify hepatic artery variations in liver grafts procured from brain-dead donors at Viet Duc Hospital and to evaluate their implications for transplantation.

Patients and Methods: Data were collected retrospectively from 2011 to 2016 and prospectively from 2017 to 2020, covering 53 liver grafts obtained from brain-dead donors.

Results: Anatomical variants were categorized according to Hiatt's classification and additional atypical patterns, with Type 1 (67.9%) being the most common, followed by Type 2 (13.2%) and Type 3 (7.6%) variants were observed. Noteworthy typical variants included right hepatic arteries originating from the gastroduodenal artery. While 15 of 17 anatomical variations were detected intraoperatively, two were only identified during back-table preparation. Reconstruction was required in 7.5% of cases, primarily involving the right hepatic artery. Post-transplantation, hepatic artery complications were rare and not significantly associated with anatomical variations.

Conclusions: The findings emphasize the importance of meticulous dissection and preoperative imaging to accurately map hepatic arterial anatomy and to avoid intraoperative complications. Awareness and careful management of hepatic artery variations can contribute to improved graft outcomes and reduce the risk of arterial complications post-transplantation.

Keywords: liver transplantation, hepatic artery, brain death.

Introduction

In organ transplant surgery, the process of organ procurement and preservation is critical to the success of transplantation. K. Boudjema [1] aptly refers to this stage as “le nerf de la guerre”, underscoring its

importance. An ideal graft must retain both anatomical and functional integrity. Among the anatomical structures within the liver graft, the hepatic artery is of particular significance and is prone to considerable anatomical variability. The incidence of hepatic artery

anatomical variations during organ procurement and in autopsies has been reported to vary significantly across studies, ranging from 20% to 46% [3]. Some studies have indicated that hepatic artery injuries are more common in cases with anatomical variations than in those with a typical hepatic artery structure [4]. Reconstruction methods for right hepatic arteries with abnormalities vary across studies: some authors prefer anastomosis with the splenic artery, while others choose the gastroduodenal artery. The purpose of this study is to describe the anatomical variations in hepatic arteries of liver grafts obtained from brain-dead donors at Viet Duc Hospital.

Patients and Methods

This study includes all brain-dead donors from whom liver grafts were obtained, dissected on a back-table, and subsequently transplanted from May 2010 to May 2020.

The medical record of each case includes the surgical protocol and the record of organ procurement and back-table procedure fully describing the abdominal and liver exploration, the organ procurement, the organ washing, and the anatomical structure of the hepatic artery.

Methods

A descriptive study was conducted combining retrospective analysis of medical records from 2011 to December 2016, and a prospective analysis of medical records from January 2017 to March 2020.

Liver procurement and back-table procedure were performed following a standardized protocol established by Trịnh Hồng Sơn, Nguyễn Tiến Quyết, and collaborators [5], [6], [7].

Research Variables

The study documents the types and frequencies of anatomical types/variants of hepatic artery based on Hiatt's classification, which includes six types (Fig. 1). Other atypical anatomical types/variants not covered in this classification were also documented.

Timing of Detection of Abnormalities (preoperatively, intraoperatively, or during back-table preparation).

Hepatic artery reconstruction techniques.

The study also reviews early post-transplant complications (within 30 days) associated with the hepatic artery [8]: thrombosis (diagnosed via Doppler ultrasound, angiography, or multi-slice CT), artery stenosis (defined by a luminal narrowing >50%, a resistive index $[RI] = (\text{peak systolic velocity} - \text{end-diastolic velocity}) / \text{peak systolic velocity} < 0.5$, and peak systolic velocity >400 cm/s), pseudoaneurysms (detected via arterial imaging of angiography), and hepatic artery bleeding (determined by bleeding through drainage, angiographic intervention, or reoperation).

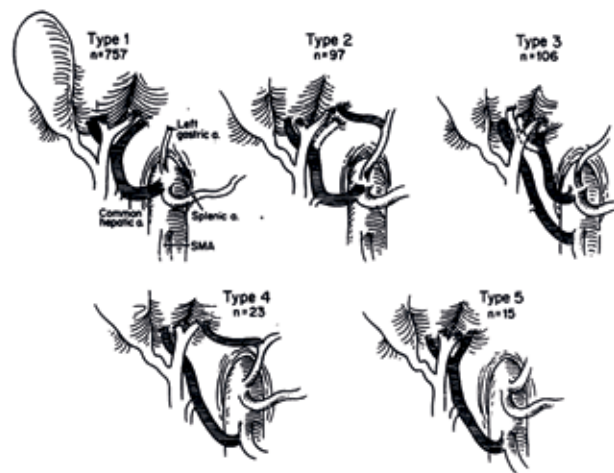


Figure 1: Hiatt's classification for variations found in hepatic artery anatomy

Type 1: Normal anatomy

Type 2: LHA branch/accessory LGA

Type 3: RHA branch/accessory SMA

Type 4: type I and II association

Type 5: CHA branch SMA

Type 6: CHA aorta branch

(Source: Hiatt, Ann Surg 1994 [2])

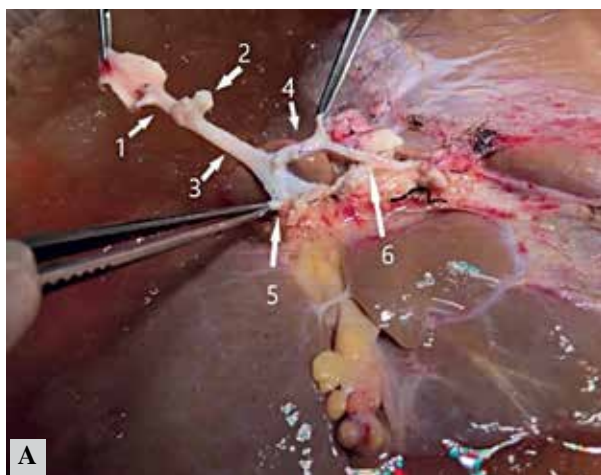
LHA: Left hepatic artery; RHA: Right hepatic artery; CHA: Common hepatic artery; LGA: Left gastric artery; SMA: Superior mesenteric artery

Results

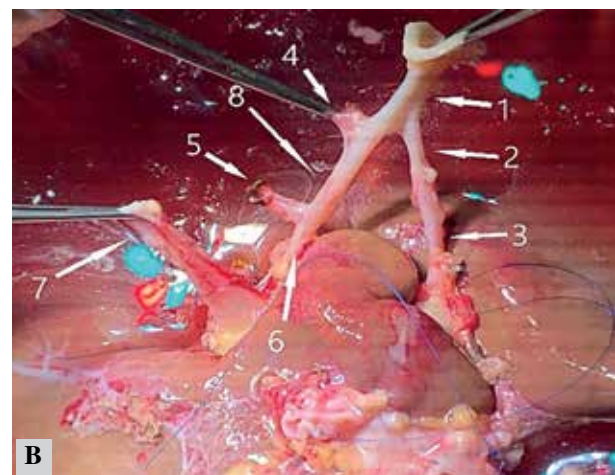
From May 2010 to May 2020, at Viet Duc Hospital, 53 cases of multi-organ procurement from brain-dead donors included liver grafts, which were subsequently transplanted into compatible recipients.

Table 1: Frequency of Hepatic Artery Anatomical Variants

Type	n	Percentage (%)	Specific Description
Type 1	36	67.9	CHA arising from the celiac trunk, bifurcating into the proper hepatic artery and gastroduodenal artery; proper hepatic artery dividing into left and right hepatic arteries
Type 2	7	13.2	LHA arising from the LGA within the lesser omentum
Type 3	4	17.6	RHA arising from the SMA, coursing posterior to the common bile duct
Type 5	1	1.9	CHA originating from the SMA, posterior to the portal vein
Other Variants	5	9.4	(1) Absence of gastroduodenal artery (GDA) (2) RHA arising from the GDA division, curving downward along the lower part of the hepatic pedicle just above the pancreas, then moves towards the liver hilum, passing in front of the common bile duct (3) Small accessory RHA from GDA: small branch of the RHA originates near the origin of the GDA and continues upwards along the hepatic pedicle (in 2 cases) (4) Accessory RHA from GDA. Its origin is low, at the level of the superior border of the pancreas, 1.7 cm from the origin of GDA. It curves downward along the lower part of the hepatic pedicle, right at the superior border of the pancreas, then courses towards the liver hilum, passing in front of the common bile duct. Accessory LHA arises from the LGA



1 – Celiac trunk, 2- Splenic artery, 3- Common hepatic artery, 4- Gastroduodenal artery, 5 -Left hepatic artery, 6 – Right hepatic artery



1 – Celiac trunk, 2- Left gastric artery, 3- Left hepatic artery, 4 – Splenic artery, 5 - Gastroduodenal artery, 6- Right hepatic artery, 7-Portal vein, 8- Common hepatic artery

Figure 2. Hepatic artery anatomical variations of the graft
(A: a rare variant, RHA branch gastroduodenal artery and B: Type 2, LHA branch LGA)

Source: BN L T N, 49y.o, and Đinh T H T H, 33 y.o

Table 2: Timing of Detection and Intraoperative Injury Rates for Hepatic Artery Variants

Variant Type	Detected times			Intraoperative Injury	Management approach
	Pre-op	Intra- op	Back- table		
Type 2	0/7	7/7		0	Preserved LHA
Type 3	0/4	4/4		0	Anastomosis of RHA to gastroduodenal artery
Type 5	0/1	1/1		0	Cutting the artery at the origin of the CHA
Other Variants (1)	0/1	1/1		0	Structure-preserving dissection
Other Variants (2)	0/1	1/1		0	Preserved RHA
Other Variants (3)	0/2		2/2	0	Preserved accessory RHA
Other Variants (4)	0/1	1/1		0	Low resected gastroduodenal artery and preserved RHA
Total	0/17	15/17	2/17	0	

Occurrence of hepatic artery-related complications in two groups: those with normal anatomy (n=36) and those with anatomical variations (n=17) after a transplant:

Hepatic artery stenosis and bleeding occurred in 1 patient in the normal anatomy group, respectively, but there were no cases in the anatomical variation group.

Pseudoaneurysm was not observed in either group.

Discussion

The observed rate of hepatic artery anatomical variations in this study was 32.1%, a median prevalence compared to global reports. This rate aligns with findings from studies on deceased donors, such as those by Andújar (30%), Hiatt (24.3%), Makisalo (24%), Trịnh Hồng Sơn (24-25%) [3], [2], [9], [10]. However it is lower than rates found in studies based on cadaver dissection or imaging diagnostics, such as those by Suzuki (46.5%), Covey (39%) [11], [12].

Regarding the prevalence of specific types of variations, this study aligns with findings from other researches with rates of Type 2, Type 3, and Type 5 variations at 13.2%, 7.6%, and 1.9% respectively.

In a study by Karakoyun et al. [13] with a sample of 409 deceased donors, Type 2, Type 3, and Type 5 variations were observed at rates of 12.9%, 11%, and 1%, respectively. Domestic research by Trịnh Hồng Sơn [14] also reported similar frequencies for Type 2 and Type 3 variations (11,6 % and 10,6 %). In addition to the common anatomical variations of the hepatic artery as mentioned above, we observed five cases displaying four anatomical patterns that are not classified by Michels or Hiatt. Among these rare variations, two cases warrant particular attention: one where the right hepatic artery bifurcates early at the division of the gastroduodenal artery, and another where the right hepatic artery originates directly from the gastroduodenal artery. Global research has also documented these rare variants at low frequencies, with Gruttadauria et al. [15] identifying right hepatic artery origination from the gastroduodenal artery in 0.14% of 701 donor cases, the prevalence of this anatomical variation in the study by Karakoyun et al. was 2 out of 409 cases [13]. Both cases in our study of replaced right hepatic artery originating from the gastroduodenal artery and displaying early branching shared a

common pathway: the artery coursed low through the hepatic hilum, parallel to the superior border of the pancreas, and ascended anterior to the common bile duct. Thus, when examining the hepatic hilum for anatomical variations of the hepatic artery, in addition to identifying the left hepatic artery within the lesser omentum and the right hepatic artery posterior to the hilum, it is critical to inspect for any right hepatic artery branches running anterior to the common bile duct. If an aberrant artery is identified in this location, meticulous dissection of the common hepatic artery, gastroduodenal artery, and the right hepatic artery branch is essential, and the gastroduodenal artery should not be transected until the hepatic artery's anatomy is confirmed. Studies by Gruttadauria and Karakoyun do not provide detailed descriptions of the pathway of the right hepatic artery in such rare variants, emphasizing a gap in the literature on this subject.

In terms of preoperative detection of hepatic artery variations, no cases in our study were identified prior to surgery. This was because none of the patients with anatomical variations had undergone abdominal CT imaging; instead, ultrasound was used to assess the morphology and dynamics of the abdominal vasculature preoperatively. Although abdominal ultrasound remains a feasible tool for identifying hepatic artery variations [16]. M. Bret et al. [17] reported a sensitivity of 71% and specificity of 96% for detecting right hepatic artery variations with ultrasound. However, no studies have specifically evaluated the utility of pre-procurement ultrasound for hepatic artery variations in brain-dead donors. Our institution's experience suggests that this limitation likely stems from the technical challenges of visualizing the deep hepatic artery in brain-dead patients, where abdominal tissues are often edematous and patient positioning is limited. The majority of anatomical variations (15/17) were identified intraoperatively through meticulous dissection of the hepatic hilum. Two cases were only detected during back-table preparation due to the very small caliber of the accessory right hepatic

artery, which originated close to the gastroduodenal artery root and ascended directly into the hilum.

Regarding the management of hepatic artery variations, four cases (7.5%) required arterial reconstruction, all involving a right hepatic artery arising from the superior mesenteric artery. In each case, anastomosis of the right hepatic artery to the gastroduodenal artery was performed. For left hepatic artery variants arising from the left gastric artery, 7 out of 8 cases preserved the artery, with one case necessitating ligation due to a diminutive left hepatic artery originating near the cardia and traversing the lesser omentum to supply the left lobe. Despite the diminutive left hepatic artery non-reconstruction, in this case, the graft function remained normal after transplantation. A single-center study by E. Melada et al. [18] on 620 liver grafts found an anatomical variation rate of 21.4% (133/620), with 9% (56 grafts) requiring arterial reconstruction, predominantly due to right hepatic artery variants, and only one case in which the left hepatic artery originated from the aorta and one case in which the common hepatic artery arose from the superior mesenteric artery. These findings are consistent with our study and with other international reports, indicating that most arterial reconstructions involve either accessory or replaced right hepatic arteries. Reconstruction techniques primarily included anastomosis to the splenic artery (46%), "fold over" technique, in which the origin of the superior mesenteric artery is anastomosed to the celiac trunk base on an aortic patch, with the distal superior mesenteric artery connected to the recipient artery (26%), and anastomoses to the gastroduodenal or left gastric artery at rates of 10.7% and 3.6%, respectively. Based on over 300 arterial reconstructions for liver transplants, Rafaella et al. [19] proposed the following guidelines: for accessory right hepatic arteries larger than 2 mm, an end-to-end anastomosis with the splenic artery is preferred as it maximizes perfusion pressure from the celiac trunk; for arteries smaller than 2 mm, anastomosis to the gastroduodenal artery tip is recommended.

An alternative strategy involves creating a single blood supply source by connecting the celiac trunk to the superior mesenteric artery. If the right hepatic artery is divided during dissection, two options are suggested: if the remaining artery is short, an end-to-end anastomosis with the gastroduodenal artery is preferable, potentially using an autologous graft from the left gastric or splenic artery if needed. If the division occurs at the origin from the superior mesenteric artery, anastomosis techniques can be selected based on artery size as outlined above. In our experience, the selection of anastomosis site for the right hepatic artery depends on the graft's arterial configuration; if the artery is anastomosed to the splenic artery, the connection should occur at the celiac trunk on the graft. If the surgeon opts to anastomose the hepatic artery at the common hepatic artery on the graft, the right hepatic artery should be connected to the gastroduodenal artery.

Concerning the impact of hepatic artery anatomical variations on transplant outcomes, a meta-analysis by Bekker et al. [20] identified hepatic artery variations, particularly those requiring arterial reconstruction and involving arterial injury during procurement, as factors associated with an increased risk of hepatic artery thrombosis post-transplantation. However, studies with large patient samples have shown no significant differences in complication rates between grafts with normal and those with variant anatomies. A study by Schroering et al. [21] analyzed the effect of hepatic artery variations on liver transplant outcomes in a cohort of 1,145 whole liver transplants. The study found that 68% of liver grafts had normal arterial anatomy, while 19% required back-table hepatic artery reconstruction; all 161 cases with replaced or accessory right hepatic arteries were reconstructed via anastomosis to the gastroduodenal artery. Results showed a hepatic artery thrombosis rate of 1% (15 cases) with no significant difference in complication rates between grafts with normal and variant arterial anatomy nor between those requiring and not requiring arterial reconstruction. In our study, two

cases exhibited hepatic artery-related complications unrelated to arterial variations; one involved hepatic artery thrombosis due to bile leakage, and another had bleeding from a minor branch unrelated to anatomic variations of the graft.

Conclusion

Hepatic artery variations are observed in approximately 30% of cases and therefore, must be carefully considered during organ procurement to avoid injury to this vital structure of the graft. In addition to inspecting the lesser omentum and posterior hilum for potential left and right hepatic artery variations, it is essential to perform a low transection of the gastroduodenal artery accounting for the possibility that the right hepatic artery may originate from this vessel, which may be challenging to identify intraoperatively.

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