Original Article

Study of Relationship Between the Blood Supply of the Extrahepatic Bile Duct and Duct Supply Branches from Gastroduodenal Artery on Imaging and Anatomy

Jie Dai[1], Xiao-Feng Wu[2], Chun Yang[3], Hong-Jun Li[2], Ya-Liang Chen[3], Guo-Zhen Liu[1], Yi-Zhi Song[3], Huan-Huan Wu[1], Jin-Li Ding[2], Ning Li[2]

[1]Centre for Clinical Pathology, Capital Medical University, Beijing 100069, China
[2]Department of Radiology, Beijing You'an Hospital, Capital Medical University, Beijing 100069, China
[3]Department of Anatomy, Capital Medical University, Beijing 100069, China

Jie Dai and Xiao-Feng Wu contributed equally to this work.

Abstract

Background: Liver transplantation has become the treatment of choice for patients with end-stage acute or chronic hepatic disease. Bile duct complications are common events after liver transplantation. The aim of this study was to evaluate the blood supply of the human bile duct and identify the underlying mechanisms of bile duct complications after liver transplantation.

Methods: The duct supply branches from gastroduodenal artery and blood supply of extrahepatic bile duct system were re-evaluated through selective hepatic angiography from 600 patients. In addition, 33 cadavers were injected with latex casting material into the common hepatic artery, then the extrahepatic bile duct and the branches from the common hepatic artery were carefully dissected to visualize the gastroduodenal artery and its branching to the extrahepatic bile duct.

Results: The bile duct artery arose from the branch of the gastroduodenal artery in 8.1% (49/600). Of these 49 individuals, the bile duct artery was supplied by the gastroduodenal artery (61.22%, 30/49), the proper hepatic artery (14.29%, 7/49), or both the gastroduodenal artery and the proper hepatic artery (24.49%, 12/49). In our study of 33 cadavers, the percentage that the bile duct artery arose from the gastroduodenal artery was 27.27%. The blood supply to the bile extrahepatic bile ducts was divided into different segments and formed longitudinal and arterial network anastomosed on the walls of the duct.

Conclusions: There is a close relationship between the duct supply branches from gastroduodenal artery and the blood supplying patterns of the extrahepatic bile duct system. In liver transplant surgery, the initial part of the gastroduodenal artery is preferred to be preserved in the donor liver. It is of great significance to improve the success rate of operation and reduce complications.

Key words: Angiography; Bile Duct Complication; Extrahepatic Bile Duct; Duct Supply Branches From Gastroduodenal Artery; Latex Casting Mold

Introduction

Bile complication after liver transplantation is one of the most important factors in transplant failure, such as anastomotic biliary stricture (ABS).[1,2] The rate of non-anastomotic biliary stricture (NABS, also called ischemic biliary stricture) is as high as 9.60%.[3] There are many reasons leading to NABS, such as thrombus, infection, rejection, vascular variation, etc.[4-6] Meanwhile, it is still unclear about the physiological function, arterial supply and venous return of the liver.[7] There is significant clinical liver transplantation data in Liver Transplantation Center, Beijing You'an Hospital affiliated to Capital Medical University, demonstrating that reserving the initial part of the gastroduodenal artery in the donor liver reduces the incidence of NABS after liver transplantation. However, the mechanism is not clear. In order to clarify the relationship between the blood supply of the extrahepatic bile duct system and gastroduodenal artery branch, selective hepatic artery angiography and a vascular casting technique were used to observe the gastroduodenal artery and its biliary supply branches, and the blood supply of the extrahepatic bile duct system, especially the microcirculatory distribution. The data about the microcirculatory distribution was collected, from which the anatomical basis for NABS was surveyed. The goal was to clarify the correlation between the blood supply of extrahepatic bile duct system and biliary complication, and to provide more evidence for reserving the initial part of gastroduodenal artery in the donor liver when preparing the donor liver.

Access this article online

Quick Response Code:

Website: www.cmj.org

DOI: 10.4103/0366-6999.150097

Address for correspondence: Prof. Ning Li, Department of Radiology, Beijing You'an Hospital, Capital Medical University, Beijing 100069, China
E-Mail: lining@bjyah.com.cn

Methods

From January 1996 to November 2005, imaging findings of 600 patients were obtained from Beijing Chaoyang and Beijing You'an hospitals, Capital Medical University, China. These patients (420 men and 180 women aged from 18 to 80 years old) underwent selective hepatic angiography at Department of Invasive Technology. All patients enrolled in this study were diagnosed with hepatic occupying lesions. The study protocol was approved by the Institutional Review Board of Capital Medical University, and written informed consent was signed by all patients before starting the selective hepatic angiography. No complications occurred during the operation. The angiographic images were interpreted independently in a blinded fashion by two authors. These authors assessed the existence of the gastroduodenal artery and its branching to the bile duct.

Thirty-three adult cadavers (29 men and 4 women, age from 40 to 80 years old) with no hepatobiliary diseases were obtained from the Department of Anatomy, Basic Medical School, Capital Medical University, Beijing, China. The study protocol was approved by the Ethics Committee of Capital Medical University. After ligation of the splenic artery and left gastric artery, the cadavers were injected with red synthetic latex via the common hepatic artery, and dissected 7 days later. The extrahepatic bile duct and the branches from the common hepatic artery were carefully dissected to visualize the gastroduodenal artery and its branching to the extrahepatic bile duct.

Results

The incidence and supply type of gastroduodenal artery bile duct branch

Imaging findings from the 600 patients were summarized in Table 1.

According to imaging findings, the supply branches were divided into the trunk type (the branch was thicker, larger blood vessels) and branching type (delicate vascular network). The selective hepatic angiographic findings showed that in 49 of the 600 patients (8.10%), the branch to the bile duct from the gastroduodenal artery was observed originating within approximately 3 cm of the proximal point, and went upward to the hepatic portal in the hepatoduodenal ligament. In these 49 patients, three types of arterial supply to the extrahepatic bile duct were observed: the gastroduodenal artery predominantly (Type I), the gastroduodenal artery and the proper hepatic artery equally (Type II), and the proper hepatic artery predominantly (Type III). Each type had its own characteristics.

Table 1: Summary of imaging findings in 49 patients

BDST	Paths	Numbers of patients (*n* (%))
Type I		30 (61.22)
TT	Upwards	26 (53.06)
BT	Upwards	4 (8.16)
Type II		12 (24.49)
BTT	Anastomotic	10 (20.41)
BBT	Anastomotic	2 (4.08)
Type III		7 (14.29)
TT	Downwards	7 (14.29)

Type I: The gastroduodenal artery predominantly; Type II: The gastroduodenal artery and the proper hepatic artery equally; Type III: The proper hepatic artery predominantly; BDST: Bile duct supply type; TT: Trunk type; BT: Branching type; BTT: Both the trunk types; BBT: Both branching types.

Type I was observed in 30 of the 49 patients (61.22%). In 26 of these 30 patients, the bile duct branch from gastroduodenal artery showed the trunk type [Figure 1a], and the bile duct branch from proper hepatic artery showed the branching type in 26 patients. In the remaining 4 patients, the gastroduodenal artery bile duct supply branch showed the branching type.

Type II was evident in 12 of 49 patients (24.49%). Among these 12 patients, both bile duct branches from the gastroduodenal artery and the proper hepatic artery showed the trunk type in 10 patients (20.41%) [Figure 1b], which included typical double trunk type (from the gastroduodenal artery and the proper hepatic artery) in 8 patients, the right hepatic artery in 1 patient and cystic artery in 1 patient. In the remaining 2 patients (4.08%), we found the supply branches were branching type [Figure 1c].

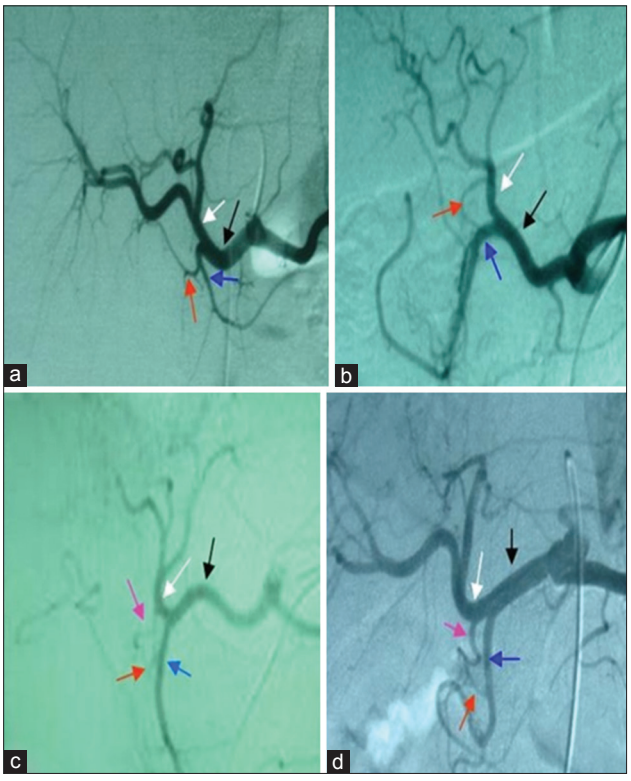

Figure 1: Image findings were obtained with the selective arterial angiography. Images showed the CA (black arrow), the GA (blue arrow), the GA supply branch duct type (red arrow), the PHA (white arrow), and the PHA bile duct supply branch (pink arrow). (a) GA bile duct supply branch showed the trunk type and ran upward. (b) Both GA and PHA bile duct supply branch showed the trunk type, and formed an arterial circle. (c) Both GA and PHA showed the branching type. (d) Image showed PHA (the trunk type). CA: cystic artery; GA: gastroduodenal artery; PHA: proper hepatic artery.

Type III was present in the remaining 7 patients (14.29%), which included the proper hepatic artery predominantly in 6 patients and the right hepatic artery in 1 patient. The bile duct supply branches, from the proper hepatic artery (the trunk type) and from the gastroduodenal artery (the branch type), showed an anastomotic network [Figure 1d].

The blood supply of the extrahepatic bile duct and microvascular distribution

In all 33 specimen casts, the blood supply of extrahepatic bile duct was mainly obtained from the gastroduodenal artery, the proper hepatic artery, the right hepatic artery, the cystic artery and the posterior portal vein artery. The bile duct branch from gastroduodenal artery was present in 9 specimens [27.27%, Figure 2a]. The blood supply to the superior and inferior parts of the extrahepatic bile ducts were from two groups of arteries, and the blood supply to the middle part was from another artery in some specimens. According to the origin of the blood supply, the blood supply to bile duct was divided into three types: (1) the cystic artery (or the right gastric artery)–gastroduodenal artery type, (2) the cystic artery–proper hepatic artery type, and (3) the posterior portal vein artery–proper hepatic artery type. The superior part of the extrahepatic bile duct was mainly supplied by the branches of the cystic artery, the proper hepatic artery and the right gastric artery. The blood supply to the inferior part was mainly from the gastroduodenal artery and the lower branches of the proper hepatic artery. In the middle part, the blood supply could be from the posterior portal vein artery and the branches of the proper hepatic artery, or from the anastomotic branches of the upper and lower artery branches.

The arteries ran closely along the longitudinal surface of the extrahepatic bile duct. In the upper part, the cystic artery, the proper hepatic artery and the right gastric artery formed an arterial network, which ran downward. In the lower part, the branches from the gastroduodenal artery and the lower branches of the proper hepatic artery traveled upward along the surface of the extrahepatic bile duct. In the middle part, the arterial branches from the upper and lower origins formed a longitudinal anastomotic chain [Figure 2b], in 23 of 33 specimens (69.70%). In 6 of 33 specimens (18.18%), the arterial branches from the proper hepatic artery and the posterior portal vein artery ran transversely. In 4 specimens (12.12%), the arterial branch to the middle part was absent [Figure 2c]. A summary of blood supply of the middle part of the extrahepatic bile duct in 33 specimens were shown in Table 2.

Discussion

In 1960, Michels[8] dissected 200 cadavers and classified hepatic arteries into 10 types according to the blood supply, and this classification was approved. Based on 1000 hepatic operations, Hiatt and his group[9] simplified the hepatic arteries into 6 types in 1994. The variation of hepatic arteries is reported to be 20%-45%.[10-13] At present, origins of the blood supply to the extrahepatic common bile ducts are still unclear. Kobayashi *et al*.[14] found that the inner layers of comparatively large bile ducts are made up of capillaries, which open at the inferior surface of the epithelial layer and distribute regularly, just like chains. Interlobular ducts and small bile ducts are surrounded by a vascular plexus forming from irregularly distributing small round cavity-like capillary. For the blood supply of the extrahepatic bile ducts, the extrahepatic bile duct artery might be derived from the cystic artery, common hepatic artery, gastroduodenal artery, posterior portal vein artery, and arteria pancreaticoduodenal superior posterior.[15-18] For the blood distribution to extrahepatic bile ducts, Gunji *et al*.[19] and Cho *et al*.[20] investigated the intersegmental arterial communication between the right and left hepatic artery, using acrylic acid cast and latex resin cast specimens, respectively. Chen *et al*.[21] had analyzed the relationship between the blood supply of bile duct and duct hemorrhage, forwarding an opinion that the hepatic porta, and intraduodenal portions of the bile duct are abundantly supplied by an arterial

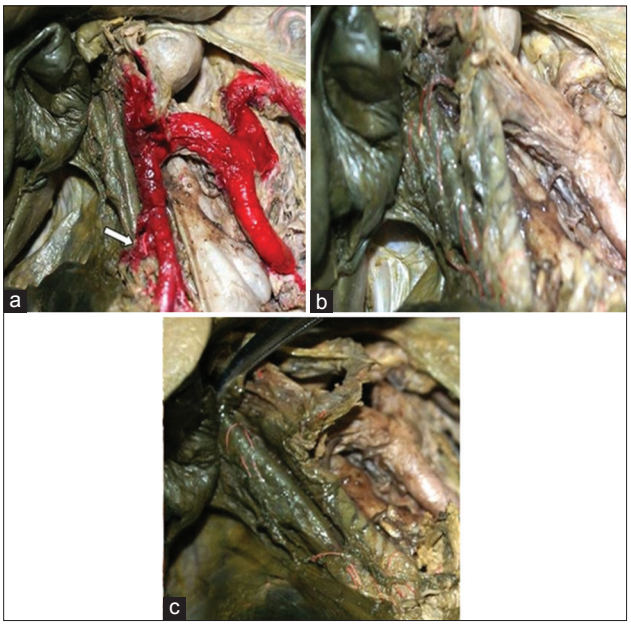

Figure 2: Specimens were obtained with casting. (a) bile duct branch from GA showed the trunk type (white arrow). (b) The arterial branches from the upper and lower origination formed a longitudinal anastomotic chain (red color). (c) The arterial branch of the middle part was absent.

Table 2: Summary of the blood supply in the middle part of the extrahepatic bile duct in 33 specimens

Origination	Distribution	Numbers of specimens (*n* (%))
Upper (branches of CA, PHA, RGA); Lower (branches of the GA, PHA)	Longitudinal anastomosis	23 (69.69)
Branches of PPVA, PHA	Transverse	6 (18.18)
Lack of arterial branches	–	4 (12.12)

CA: Cystic artery; PHA: Proper hepatic artery; RGA: Right gastric artery; GA: Gastroduodenal artery; PPVA: Posterior portal vein artery.

network or arterial circle, and are prone to bleed. While for the common bile duct, the blood supply is derived from a longitudinal anastomotic chain, and forms from the upper and lower group of arteries, and tends to be ischemia. However, there are quite a few reports on the bile duct supply branch from gastroduodenal artery.

At the Transplantation Center of Beijing You'an Hospital, Capital Medical University, clinical studies indicated that the incidence of non-anastomotic biliary stricture is decreased after retaining the first part of gastroduodenal artery of donor liver. The present arteriography data of the common hepatic artery and its branches indicated that in about 8.10% (49/600) of people, the first part of the gastroduodenal artery separated into branches to supply the bile ducts. Using a microvascular latex cast method, the results showed that 27.27% (9/33) of people's bile duct blood supply was separate from the first part of the gastroduodenal artery. This different incidence data may be due to a variety of imaging samples from patients with hepatobiliary disease; some patients had been treated with hepatic artery embolizations, which resulted in the hepatic arteriography displaying a false negative; in addition, our group obtained other clinical data which also showed a lower incidence of NABS by an improved operation method which retained the gastroduodenal artery. In the few years, the newly CT angiography has improved the accuracy of the imaging. It is suggested that the real incidence of bile duct branches from gastroduodenal artery in the clinical cases may be higher than the incidence determined by imaging results.

In addition, the results of latex resin cast specimens provided new evidence about the blood supply and the distribution characteristics of micrangium. In this study, the extrahepatic bile duct was divided into three portions, among which the medium part's blood supply was more complicated. We not only found a longitudinal anastomotic chain forming from the upper and lower group of arteries in this portion, but also found 18.18% of all cases had laterigrade branches from the posterior portal vein artery and the proper hepatic artery. For the hepatic artery supplying the medium part, there were also 12.12% of the segments existing in a significant ischemic zone. The anatomical variations could serve as an anatomical basis for non-anastomotic biliary stricture in some of the patients after liver transplantation. And any reason causing an artery branch cut-off could further aggravate the local ischemia. So the extrahepatic bile duct was prone to disturbance of the blood supply resulting from an arterial variation or destroyed vascular net.

Since the 1990s, with the progress of liver transplantation techniques and reduction of other complications such as rejection, non-anastomotic biliary stricture has attracted an increasing amount of attention by scholars from all over the world. Except for some of the donor liver factors (age, gender, fatty degeneration and preservation of donor liver, etc) and surgical problem (operative injury, ischemia-reperfusion, etc.), it is agreed that some arterial problems (variation of hepatic artery, thrombogenesis, hepatic arterial stricture, hypoperfusion of small artery on the wall of bile ducts, etc.) can lead to NABS.

Our experiment has clearly elaborated the micrangium on the wall of bile ducts and its travelling characteristic through latex resin cast specimens, further providing the anatomical basis for ischemic biliary complication, especially non-anastomotic stricture. As we know, the donor's live bile duct blood supply from their own hepatic artery and branches is mainly from the hepatic artery and gastroduodenal artery. The liver transplantation connects to the hepatic artery; however, many micro-arterial anastomosis of the blood supply chain is still unopened around the extrahepatic bile duct that is liable to cause ischemia of its local region. Beijing You'an Hospital is one of the largest liver transplant centers in China. In the past 4 years, nearly 1000 in-patients with hepatocarcinoma and 300 liver transplant patients are hospitalized in Beijing You'an Hospital every year. Based on our study on liver transplantation practice, we highly recommended that it is necessary to reserve the initial segment of the gastroduodenal artery to avoid a poor blood supply, and we try our best to protect the vascular net around the extrahepatic bile ducts during liver surgery.

References

1. Poley JW, Lekkerkerker MN, Metselaar HJ, Kuipers EJ, Bruno MJ. Clinical outcome of progressive stenting in patients with anastomotic strictures after orthotopic liver transplantation. Endoscopy 2013;45:567-70.
2. Jiang L, Yang J, Chen W, Zhuang W. Vascular and biliary complications after liver transplantation: interventional treatment. Chin Med J 2002;115:1679-82.
3. Guichelaar MM, Benson JT, Malinchoc M, Krom RA, Wiesner RH, Charlton MR. Risk factors for and clinical course of non - Anastomotic biliary strictures after liver transplantation. Am J Transplant 2003;13:885-90.
4. Li GM, Zhu JY, Huang L, Liu M, Wang D, Zhu FX, *et al*. Posttransplant non-anastomotic biliary stricture in consecutive 381 liver transplantations at a single center. Chin J Gen Surg 2007;22:38-42.
5. Seehofer D, Eurich D, Veltzke-Schlieker W, Neuhaus P. Biliary complications after liver transplantation: old problems and new challenges. Am J Transplant 2013;13:253-65.
6. Cursio R, Gugenheim J. Ischemia-reperfusion injury and ischemic-type biliary lesions following liver transplantation. J Transplant 2012;2012:164329.
7. Gaudio E, Onori P, Franchitto A, Pannarale L, Alpini G, Alvaro D. Hepatic microcirculation and cholangiocyte physiopathology. Ital J Anat Embryol 2005;110:71-5.
8. Michels NA. Newer anatomy of the liver and its variant blood supply and collateral circulation. Am J Surg 1966;112:337-47.
9. Hiatt JR, Gabbay J, Busuttil RW. Surgical anatomy of the hepatic arteries in 1000 cases. Ann Surg 1994;220:50-2.
10. Gruttadauria S, Foglieni CS. Doria C, Luca A, Lauro A, Marino IR. The hepatic, artery in liver transplantation and surgery: vascular anomalies in 701 cases. Clin Transplant 2001;15:350-63.
11. Soin AS, Friend PJ, Rasmussen A, Saxena R, Tokat Y, Alexander GJ, *et al*. Donor arterial variations in liver transplantation: management and outcome of 527 consecutive grafts. Br J Surg 1996;83:637-41.
12. Gao W, Zhu ZJ, Wei L, Huai MS, Jiang WT, Zhang JJ, *et al*. Protection of anomalous hepatic arteries during donor operation of liver transplantation. Chin J Hepatobiliary Surg 2006;12:610-2.

13. Miyayama S, Yamashiro M, Hashimoto M, Hashimoto N, Ikuno M, Okumura K, *et al*. Blood supply of the main bile duct from the caudate artery and medial subsegmental artery of the hepatic artery: evaluation using images obtained during transcatheter arterial chemoembolization for hepatocellular carcinoma. Hepatol Res 2013;43:1175-81.
14. Kobayashi S, Nakanuma Y, Matsui O. Intrahepatic peribiliary vascular plexus in various hepatobiliary disease: a histological survey. Hum Pathol 1994;25:940-6.
15. Stange BJ, Glanemann M, Nuessler NC, Settmacher U, Steinmüller T, Neuhaus P. Hepatic artery thrombosis after adult liver transplantation. Liver Transpl 2003;9:612-20.
16. Stapleton GN, Hickman R, Terblanche J. Blood supply of the right and left hepatic ducts. Br J Surg 1998;85:202-7.
17. Donato P, Coelho P, Rodrigues H, Vigia E, Fernandes J, Caseiro-Alves F, *et al*. Normal vascular and biliary hepatic anatomy: 3D demonstration by multidetector CT. Surg Radiol Anat 2007;29:575-82.
18. Blakolmer K, Jain A, Ruppert K, Gray E, Duquesnoy R, Murase N, *et al*. Chronic liver allograft rejection in a population treated primarily with tacrolimus as baseline immunosuppression: long-term follow-up and evaluation of features for histopathological staging. Transplantation 2000;69:2330-6.
19. Gunji H, Cho A, Tohma T, Okazumi S, Makino H, Shuto K, *et al*. The blood supply of the hilar bile duct and its relationship to the communicating arcade located between the right and left hepatic arteries. Am J Surg 2006;192:276-80.
20. Cho A, Gunji H, Koike N, Narumoto S, Asano T, Yamamoto H, *et al*. Intersegmental arterial communication between the medial and left lateral segments of the liver. Dig Surg 2007;24:328-30.
21. Chen WJ, Ying DJ, Liu ZJ, He ZP. Analysis of the arterial supply of the extrahepatic bile ducts and its clinical significance. Clin Anat 1999;12:245-9.

Received: 24-05-2014 **Edited by:** De Wang
How to cite this article: Dai J, Wu XF, Yang C, Li HJ, Chen YL, Liu GZ, Song YZ, Wu HH, Ding JL, Li N. Study of Relationship Between the Blood Supply of the Extrahepatic Bile Duct and Duct Supply Branches from Gastroduodenal Artery on Imaging and Anatomy. Chin Med J 2015;128:322-6.

Source of Support: Nil. **Conflict of Interest:** None declared.