https://doi.org/10.36570/jduhs.2022.1.1243

JDUHS

ORIGINAL ARTICLE

# Relationship between Variant Biliary and Vascular Anatomy in Living Liver Donors in Pakistani Population

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## ABSTRACT

**Objective:** To investigate the relationship of variant biliary anatomy with hepatic vascular variants in living liver donors.
**Methods:** A retrospective cross-sectional study was conducted at Shifa International Hospital, Islamabad, from January 2017 to Feb 2020. Two radiologists reviewed pre-operative Computed tomography (CT) angiography and Magnetic resonance cholangiopancreatography (MRCP) of live liver donors having the variant biliary anatomy only, in consensus. The classification of the conventional or variant hepatic artery, hepatic veins, and portal vein was done based on CT angiography scans, while biliary anatomy was characterized based on MRCP images.
Results: Of 165 liver donors with variant biliary anatomy, standard anatomy involving hepatic arteries observed in 88 (53.3%) and portal veins in 125 (75.8%) individuals. Twenty-nine (17.5%) liver donors had trifurcation pattern (B) and 26 (15.7%) had short right hepatic duct (C). Forty (24.2%) had anterior right hepatic duct (RAHD) continuing into common hepatic duct (D). In 49 (29.6%) donors, abnormal right posterior hepatic duct (RPHD) configurations draining into left hepatic duct (E) were found. In 21 (12.7%), RAHD had separate drainage into left hepatic duct (F). Trifurcation, short right hepatic artery, drainage of RPHD into left hepatic duct, and drainage of RAHD into left hepatic duct were mostly observed in conventional-Michel's I, i.e., 16 (9.7%), 12 (7.2%), 28 (16.9%), 14 (5.4%), and 88 (53.3%) respectively.
**Conclusion:** Among the biliary variants, type D and E were most frequent. There was also an increased incidence of a concurrent variant hepatic arterial supply in liver donors in presence of variant biliary drainage.
**Keywords:** Biliary Tract, Hepatic Artery, Portal Vein, Liver Transplantation, Living Donors.



## INTRODUCTION

With the advent of liver transplantation becoming the ultimate cure for end-stage liver failure and several other oncologically related therapeutic successful hepatic surgeries, including, partial hepatic resection, a comprehensive analysis of intrahepatic vascular and biliary anatomical details is essential proceeding for surgery.[1,2] The objectives of this pre-operative assessment are to select the most suitable surgical plane, avoid complications/ morbidity in donors, and at the same time identify variants in vascular/biliary anatomy which may require special surgical technique.[3,4]

For selecting appropriate donor candidates, awareness of vascular/biliary anomalies is paramount in pre-operative planning for adult living donor liver transplantation. Customarily, the right hepatic lobe of the donor is preferably transplanted to the recipient.[1] Anomalous anatomy involving the hepatic vascular and biliary supply is frequently found.[2,5,6] With the help of multi-detector computed tomographic (CT) techniques like CT angiography and magnetic resonance cholangiopancreatography (MRCP), the radiologist plays a crucial role in providing valuable information helpful in choosing the most suitable candidate and in identifying anatomic variants that may alter the surgical approach.[4,6] Based on the anatomic layout of the bile ducts, portal venous branches, and arterial supply in the portal triad, one might be able to hypothesize the correlation between the presence of anomalous bile duct and hepatic vascular patterns, and can foresee the chance of having both kinds of anomalies in a liver donor preoperatively.
To the best of our knowledge, no studies have explored the correlation between various variant biliary and hepatic vascular variants in Pakistani population. Advanced surgeries involving the hepatobiliary plane are becoming increasingly popular in Pakistan, making

7.733 years. Out of these, there were 88 (53.3%) subjects with a conventional pattern of the hepatic artery, 125 (75.8%) portal vein, and 125 (75.8%) hepatic veins. The distribution and incidences of the variant biliary, hepatic artery, portal vein, and hepatic veins are given in Table 1. Among biliary duct variant anatomy, a total of 29 (17.5%) of the liver donors had a trifurcation pattern (B) and 26 (15.7%) had a short right hepatic duct (C). At the same time, 40 (24.2%) subjects had anterior right hepatic duct (RAHD) continuing into the common hepatic duct (D). Furthermore, in 49 (29.6%) donors, abnormal right posterior duct configurations (RPHD) draining into the left hepatic duct (E) were found. Similarly, in 21 (12.7%), RAHD had separate drainage into the left hepatic duct (F). (Figure 1)

Variant hepatic arterial supply was identified in 77 (46.7%) of 165 subjects (Table-1). Michel's- 3 replaced right hepatic artery (RHA) was the most prevalent arterial variant, found in 19 (11.5%) donors. The following most common variant was accessory left hepatic artery (LHA) – Michel's 5, recorded in 18 (10.9 %) of donors, succeeded by replaced LHA – Michel's 2 in 11 (6.7 %). (Figure 2).

Portal vein variants were observed in 40 (24.2%) subjects. (Table 1). The right portal vein as the first branch of the main portal vein 23 (13.9%) was the most common variant followed by a trifurcation branching pattern in 13 (7.9 %). (Figure 3).

In contrast, the right inferior hepatic vein (RIHV) was recorded in 7 (4.2%) donors among hepatic vein

**Table 1: Sociodemographic and clinical characteristics of patients (n = 165).**

| Description | Mean | SD |
|---|---|---|
| **Age** (in years) | 30.55 | 7.733 |
| | **Frequency** | **Percentages** |
| **Biliary Variant Type** | | |
| Trifurcation(B) | 29 | 17.5 |
| A short right hepatic duct(C) | 26 | 15.7 |
| Continuation of the right anterior hepatic duct into the common hepatic duct(D) | 40 | 24.2 |
| Drainage of the right posterior hepatic duct into the left hepatic duct(E) | 49 | 29.6 |
| Drainage of the right anterior hepatic duct into the left hepatic duct(F) | 21 | 12.7 |
| **Hepatic Artery Type** | | |
| Conventional – Michel’s 1 | 88 | 53.3 |
| Replaced LHA – Michel’s 2 | 11 | 6.7 |
| Replaced RHA – Michel's 3 | 19 | 11.5 |
| Both replaced RHA/LHA – Michel's 4 | 7 | 4.2 |
| Accessory LHA– Michel’s 5 | 18 | 10.9 |
| Accessory RHA – Michel’s 6 | 4 | 2.4 |
| Accessory RHA and accessory LHA– Michel's 7 | 0 | 0 |
| Replaced RHA/ ACC LHA or replaced LHA/ACC RHA– Michel’s 8 | 3 | 1.8 |
| Origin from SMA– Michel’s 9 | 5 | 3.0 |
| Origin from LGA– Michel’s 10 | 2 | 1.2 |
| Unclassified Variant– Michel’s 11 | 8 | 4.8 |
| **Portal vein type** | | |
| Conventional | 125 | 75.8 |
| Trifurcation | 13 | 7.9 |
| RPV as first BR MPV | 23 | 13.9 |
| Seg VII branch separate branch of RPV | 1 | 0.6 |
| Seg VI branch separate branch of RPV | 3 | 1.8 |
| **Hepatic vein type** | | |
| Conventional | 124 | 75.1 |
| Right inferior hepatic vein | 7 | 0.42 |
| Accessory hepatic veins for segment VI and VII | 32 | 19.4 |

LHA: Left hepatic artery, RHA: Right hepatic artery, SMA: Superior mesenteric artery, LGA: Left gastric artery, RPV: Right portal vein it imperative that we equip ourselves with the anatomical variations in this region in Pakistani population and provide a robust database. Therefore, we aim to investigate the relationship of variant biliary anatomy in living liver donors with hepatic vascular variants in the Pakistani people.

## METHODS

This retrospective cross-sectional study was carried out at the Radiology Department of Shifa International Hospital, Islamabad, Pakistan. After approval from the institutional review board, 165 MRCP scans of potential liver donors performed during the study period meeting the inclusion criteria with variant biliary anatomy were selected. Two radiologists having 9-12 years of experience, analyzed CT scans and MRCP images of these 165 potential liver donors from the hospital database in consensus between Jan 2017 and Feb 2020.

All patients, regardless of their age and gender, who underwent CT liver angiography and MRCP for liver donation and had variant biliary anatomy were included in the study. Patients who did not meet the required liver attenuation index (LAI) and had fatty liver infiltration were excluded from the study. A total of 185 subjects were excluded from the study based on conventional biliary anatomy (n=179) and poor-quality images/motion artefacts obscuring biliary anatomy (n=6).

The sample size was calculated using the WHO sample size calculator and taking a 95% confidence level, the anticipated population proportion was 31.1% (reported incidence is between 28-34.2% in the preceding research papers[3,6], so 31.1% was considered as an average value) and absolute precision to be 7%. The estimated sample size came out to be 168, but a total of 165 liver donors were included in the study.

All the CT dynamic studies were done on Toshiba aquiline 320 slice CT. Multiplanar reconstructions of the CT angiography study were used for the evaluation of hepatic vascular patterns. The examination commenced with a non-contrast phase to obtain LAI 2" inches above diaphragm till iliac crest to evaluate the fat content in the liver. Then, arterial, and venous phases were performed using inbuilt auto-set protocols in the CT scanner ranging between 260-300 mAs with kVP set at 100-120kV at 0.8-sec gantry rotation to acquire a slice width of 1 mm. The arterial phase was obtained at the auto angiographic phase 25 sec after contrast injection with a threshold of 170 HU trigger set on the aorta, 2" inches above diaphragm till iliac crest. Venous phase was acquired after 60 seconds 2" inches above diaphragm up to the pubic bone. The contrast agents used were iopromide (Ultravist 370) or iohexol (Omnipaque 350) injected at the dose of 2 ml/kg (max. 170 ml) at the rate of 4- 5 ml/sec. Qualitative assessment of hepatic artery, portal and hepatic veins were done using Vitrea version 7.7 by image post-processing by a senior technician. Maximum intensity projections (MIP) and 3D volume-rendered images of hepatic vessels were developed. All images were sent to the Picture Archiving and Communication System (PACS) workstation and retrieved from there.

MR cholangiography imaging was performed in a 1.5T with phased array abdominal coil without contrast. Dedicated MRCP sequences consisting of axial T2 fat sat (repetition time [TR]/echo time [TE] 1500/90 ms, the field of view (FOV) 43), T1 in and out of phase breath-hold sequences (TR/TE 149/2.7 ms, flip angle [FA] 80), 2D FASE multi-slice single shot and 3D coronal RG thin slab sequences were obtained. Slice thickness was 6 mm without a gap, field of view 43 mm, and matrix 224 x 320.

The demographic data including the age and gender of liver donors were recorded. Using the radiology information system (RIS) records for liver donors who had undergone MRCP were pulled out. Then with the help of the PACS workstation, first bile duct variations on the MRCP images were classified according to Couinaud classification[7] into types (B to F) and type A excluded as conventional anatomy. Then in individuals having variant biliary anatomy only, the hepatic vasculature was evaluated using CT angiography images. Hepatic artery variants were graded using Michel's classification[7] into Michel's 1 to 11. At the same time, Cheng et al.[7] classification was used for allocating portal vein branching patterns. While hepatic venous variants were classified using Soyer's modified hepatic vein classification[1].

Data analysis was conducted using Statistical Package for Social Sciences software (SPSS version 25 (SPSS Inc., Chicago, IL, USA). Quantitative variables like age were expressed in the form of mean and standard deviation. Qualitative study variables like gender, biliary, hepatic arterial, portal, and hepatic venous types were described in terms of frequency and percentages. Cross tabulation was performed between variant Hepatic artery type and Biliary variant type.

## RESULTS

Overall, 165 individuals with variant biliary anatomy were included in the study cohort, 114 (69.1%) males, 51 (30.9%) females. The mean age of donors was 30.5 ±

**Table 2: Comparison between variant Hepatic artery type and Biliary variant type (n = 165)**

| Description | Biliary Variant Type | | | | | |
|---|---|---|---|---|---|---|
| | B n (%) | C n (%) | D n (%) | E n (%) | F n (%) | Total |
| **Variant Hepatic Artery Type** | | | | | | |
| Conventional – Michel's 1 | 16 (9.7) | 12 (7.2) | 18 (10.9) | 28 (16.9) | 14 (5.4) | 88 (53.3) |
| Replaced LHA – Michel's 2 | 3 (1.8) | 1 (0.6) | 1 (0.6) | 5 (3.0) | 1 (0.6) | 11 (6.7) |
| Replaced RHA – Michel's 3 | 0 (0) | 4 (2.4) | 10 (6.06) | 4 (2.4) | 1 (0.6) | 19 (11.5) |
| Both replaced RHA/LHA – Michel's 4 | 2 (1.2) | 1 (0.6) | 2 (1.2) | 2 (1.2) | 0 (0) | 7 (4.2) |
| Accessory LHA – Michel's 5 | 1 (0.6) | 4 (2.4) | 4 (2.4) | 9 (5.4) | 0 (0) | 18 (10.9) |
| Accessory RHA – Michel's 6 | 1 (0.6) | 2 (1.2) | 1 (0.6) | 0 (0) | 0 (0) | 4 (2.5) |
| Accessory RHA and Accessory LHA – Michel's 7 | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) |
| Replaced RHA/ Accessory LHA or replaced LHA/Accessory RHA – Michel's 8 | 1 (0.6) | 0 (0) | 0 (0) | 0 (0) | 3 (1.8) | 3 (1.8) |
| Origin from SMA – Michel's 9 | 2 (1.2) | 1 (0.6) | 2 (1.2) | 0 (0) | 0 (0) | 5 (3.0) |
| Origin from LGA – Michel's 10 | 0 (0) | 0 (0) | 0 (0) | 2 (1.2) | 0 (0) | 2 (1.2) |
| Unclassified variant – Michel's 11 | 2 (1.2) | 1 (0.6) | 2 (1.2) | 3 (1.8) | 1 (0.6) | 8 (4.8) |

LHA: Left hepatic artery, RHA: Right hepatic artery, SMA: Superior mesenteric artery, LGA: Left gastric artery, B: Trifurcation, C: A short right hepatic duct, D: Continuation of the right anterior hepatic duct into the common hepatic duct, D: Drainage of the right posterior hepatic duct into the left hepatic duct, E: Drainage of the right anterior hepatic duct into the left hepatic duct

variants. While 32 (19.3%) subjects had accessory hepatic venous drainage of segment VI, VII, or both. Comparison of biliary variant type with variant hepatic artery showed that trifurcation, short right hepatic artery, drainage of right posterior hepatic duct into the left hepatic duct, and drainage of right anterior hepatic duct into the left hepatic duct were most commonly observed in conventional-Michel's I, i.e., 16 (9.7%), 12 (7.2%), 28 (16.9%), 14 (5.4%), and 88 (53.3%) respectively. Continuation of the right anterior hepatic duct into the common hepatic duct was most commonly observed in conventional-Michel's I and replaced RHA-Michel's 3, i.e., 18 (10.9%) and 10 (6.06%) respectively. (Table 2)

## DISCUSSION

Liver transplantation and extensive hepatic surgeries as a therapeutic option for oncological disease and other indications, including abdominal trauma and pancreatico-duodenectomies, are now quite common in our country.[7] The key to having a successful liver transplant graft in a recipient is maintaining the unique balance between the arterial supply and venous drainage in the grafted liver.[8-11] Although variant anatomy is not a contraindication to liver transplantation, it can complicate vascular and biliary reconstructive surgeries. However, ignorance about these variants and associations can lead to inadvertent iatrogenic injuries with significant morbidity in donor and recipient. For example, congestive changes due to the faulty venous outflow can ultimately lead to graft failure. Similarly, biliary complications can cause significant morbidity in donors with the resultant biliary leakage or stricture formation[2,12-15]

Contributing to this is the fact that there is a severe lack of data regarding associations between variant vascular and biliary anatomy in our local Pakistani population. However, our study found that variations in the hepatic biliary, artery and portal vein configurations is comparable to other ethnicities worldwide[2,3,5,6,14].

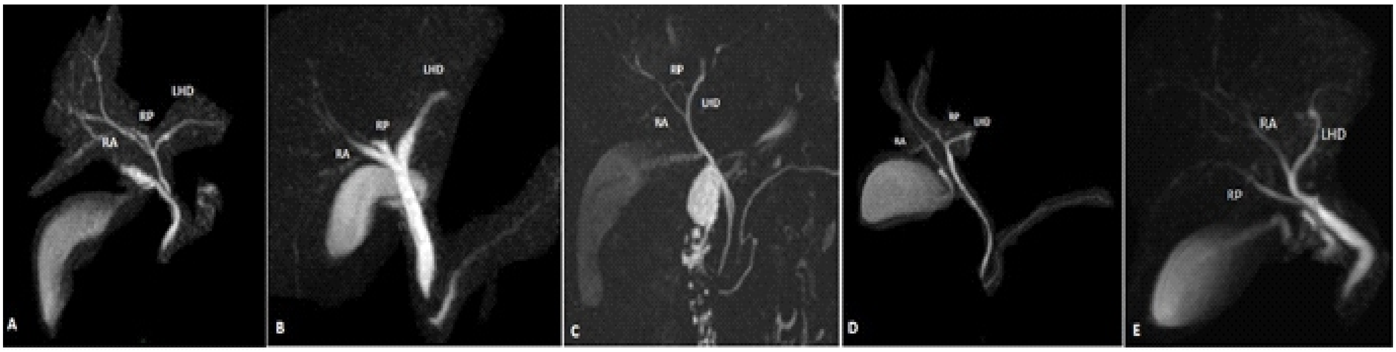


**Figure 1**. Coronal maximum intensity projection magnetic resonance (MR) angiographic images showing variant Bile duct anatomy, LHD - left hepatic duct, RA -right anterior
hepatic duct, RP -right posterior hepatic duct. (A) Trifurcation, (B) A short right hepatic duct, (C) Continuation of the right anterior hepatic duct into the common hepatic duct, (D) Drainage of the right posterior hepatic duct into the left hepatic duct and (E) Drainage of the right anterior hepatic duct into the left hepatic duct.


**Figure 2**. Coronal MIP and three-dimensional volume-rendered from CT angiography arterial phase show the most common variant hepatic anatomies, (A) Replaced LHA – Michel's 2, (B) Replaced RHA – Michel's 3 and (C) Accessory LHA– Michel's 5. CHA -common hepatic artery, GDA- gastroduodenal artery, LHA- left hepatic artery, MHA -middle hepatic artery, RHA - right hepatic artery, SMA -superior mesenteric artery.

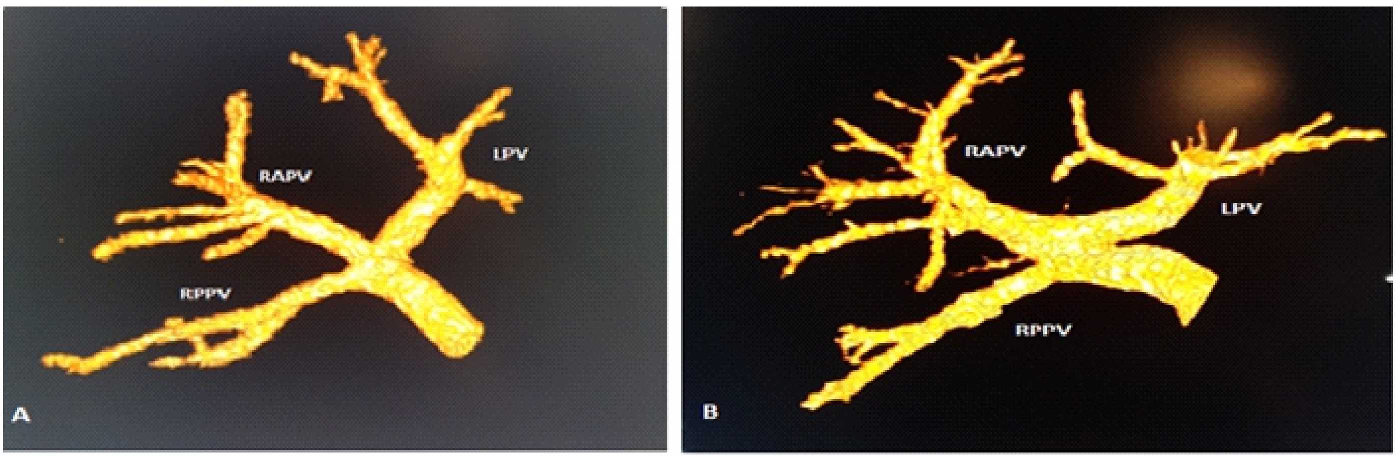


**Figure 3.** Three-dimensional volume-rendered images from CT angiography portal phase show most common portal vein variants (A) Trifurcation branching pattern with left portal vein (LPV), anterior and posterior divisions of the right portal vein (RAPV) and (RPPV) sharing common confluence and (B) variant portal venous supply with the right posterior portal vein as the first branch of the main portal vein.

We have observed that among biliary variants, Figure-1 (C-D) type D (RAHD continuing into common hepatic duct) and type E (RPHD draining into left hepatic duct) variants are frequent among our population, found in twenty four percent and thirty percent, respectively, per other studies as well[2,5,6,16,17]. Naeem M et al.[6] also describes the type E variant more commonly seen in the Pakistani population, i-e fourteen percent.

Our patient cohort found a higher relation between concurrent biliary and conventional hepatic arterial variants in donors. However, we could not find the pertinent association subtype of biliary and hepatic artery variants due to the small sample size. Nevertheless, we did see that biliary variant types D and E were more frequently seen with concurrent hepatic artery variants Michel's- 3 and Michel's- 5 figure- 2, respectively. This is a unique finding in comparison to other studies in our literature review[2-4,18,19]. Although Hanif F et al.[17] reported an increased incidence of LHA aberrations in our population; however, an accurate comparison cannot be made since our study cohort included a population with biliary variants.

Similarly, Shakeel H et al.[20] and Ahmed A et al. [21] describe a large percentage of Pakistani patients having accessory right hepatic veins or RIHVs (between 30 to 51%), which is much more in frequency compared to our study. This is perhaps due to the fact that since we took a population with variant biliary drainage, a large number of patients were already excluded from the study sample. There might have been an increased frequency of variation in hepatic venous anatomy in these patients with conventional biliary anatomy, contrary to what our study results portray.

While reviewing the literature, we found that in few studies performed in various ethnicities, the coexistence of variant biliary and portal venous anatomy is frequent. For example, Lee et al. [3], Ozsoy et al. [5,] and Taro et al. [6] reported concurrent portal venous and biliary tract variants in American, Turkish, and Japanese populations. At the same time, Macdonald et al.[1] report no significant association between hepatic arterial, portal venous, or biliary tract variants in the Canadian population.

The results of our study show that having variant biliary anatomy increases the likelihood of having variation in the pattern of hepatic arterial supply. Therefore, while planning for hepatic transplant or other hepatic surgeries, it is essential to keep in mind the patient's ethnicity and anticipate the type of variants present preoperatively to prepare for reconstruction, surgical planning, and appropriate hepatectomy plane[22-25].

Our study has few limitations; firstly, this is a single-center study with small sample size. Therefore, the results of this study need to be consolidated by a larger sample size multicentric study as an accurate representation of our population. Secondly, we have relied solely on the findings of MRCP for biliary variants and CT liver dynamic scans for vascular variants, which is the current pre-operative workup in our department.

A comprehensive pre-operative analysis of biliary and vascular liver donors is crucial in planning the possible safe extent of hepatic resection. It allows the liver transplant team to devise and formulate countermeasures for possible complications which may result in biliary/vascular compromise and eventual graft failure.

## CONCLUSION

Our study concludes that among the biliary variants, type D and E are the most frequently found in our population. There is also increased incidence of a concurrent variant hepatic arterial supply in liver donors in presence of variant biliary drainage. Therefore, the relationship between variant biliary and vascular anatomy across different ethnicities need due consideration while planning hepatic transplant, both by radiologists and surgeons. For that, there should be the establishment of robust interdepartmental cooperation and communication.

**AUTHORS' CONTRIBUTION:** LM: Corresponding author, data collection/ interpretation, drafting the manuscript, final approval to be published. SS: Data collection/interpretation, critical revision of the manuscript and editing, and final publication approval. SA: Data collection, critical revision of the manuscript, final approval to be published. BYF: Data collection, final approval to be published.

**ETHICAL APPROVAL:** This study was approved by Institutional Review Board & Ethics Committee, Shifa International Hospitals Ltd Islamabad, Pakistan.

**CONFLICT OF INTEREST:** The authors declare no conflict of interest.

**FUNDING:** None declared by authors.

**DISCLAIMER:** The abstract of this paper has been presented as an oral presentation at ECR 2021, Vienna.

Received: September 12, 2021

Accepted: November 10, 2021

## REFERENCES


1. Macdonald DB, Haider MA, Khalili K, Kim TK, O'Malley M, Greig PD, et al. Relationship between vascular and biliary anatomy in living liver donors. Am J Roentgenol 2005; 185:247-52. doi : 10.2214/ajr.185.1.01850247
2. Catalano OA, Singh AH, Uppot RN, Hahn PF, Ferrone CR, Sahani DV. Vascular and biliary variants in the liver: implications for liver surgery. Radiographics 2008; 28:359-78. doi: 10.1148/rg.282075099Lee
3. Lee VS, Morgan GR, Lin JC, Nazzaro CA, Chang JS, Teperman LW et al. Liver transplant donor candidates: associations between vascular and biliary anatomic variants. Liver Transplant 2004 ; 10:1049-54. doi: 10.1002/lt.20181
4. Schroeder T, Radtke A, Kuehl H, Debatin JF, Malagó M, Ruehm SG. Evaluation of living liver donors with an all-inclusive 3D multi-detector row CT protocol. Radiology 2006; 238:900-10. doi : 10.1148/radiol.2382050133
5. Ozsoy M, Zeytunlu M, Kilic M, Alper M, Sozbilen M. The results of vascular and biliary variations in Turks liver donors: comparison with others. ISRN Surg 2011; 2011:367083. doi: 10.5402/2011/367083
6. Naeem MQ, Ahmed MS, Hamid K, Shazlee MK, Qureshi F, Ullah MA. Prevalence of Different Hepatobiliary Tree Variants on Magnetic Resonance Cholangio-pancreatography in Patients Visiting a Tertiary Care Teaching Hospital in Karachi. Cureus 2020 ; 12: e12329. doi: 10.7759/cureus.12329
7. Dar FS, Zia H, Hafeez Bhatti AB, Rana A, Nazer R, Kazmi R, Khan EU, et al. Short term donor outcomes after hepatectomy in living donor liver transplantation. J Coll Physicians Surg Pak 2016; 26:272-6.
8. Girometti R, Pancot M, Como G, Zuiani C. Imaging of liver transplantation. Eur J Radiol 2017; 93:295-307. doi: 10.1016/j.ejrad.2017.05.014
9. Hecht EM, Kambadakone A, Griesemer AD, Fowler KJ, Wang ZJ, Heimbach JK, et al. Living donor liver transplantation: overview, imaging technique, and diagnostic considerations. Am J Roentgenol 2019; 213:54-64. doi: 10.2214/AJR.18.21034
10. Cheng YF, Huang TL, Chen CL, Chen YS, Lee TY. Variations of the intrahepatic bile ducts: application in living related liver transplantation and splitting liver transplantation. Clin Transplant 1997; 11: 337– 340.
11. Choi TW, Chung JW, Kim HC, Lee M, Choi JW, Jae HJ, et al. Anatomic variations of the hepatic artery in 5625 patients. Radiol Cardiothorac Imaging 2021; 19;3:e210007. doi: 10.1148/ryct.2021210007
12. Jhaveri KS, Guo L, Guimaraes L. Current state-of-the-Art MRI for comprehensive evaluation of potential living liver donors. Am J Roentgenol 2017; 209:55-66. doi: 10.2214/AJR.16.17741
13. Santosh D , Goel A, Birchall IW, Kumar A, Lee KH, Patel VH et al. Evaluation of biliary ductal anatomy in potential living liver donors: comparison between MRCP and Gd-EOB-DTPA-enhanced MRI. Abdom Radiol 2017; 42:2428-35. doi:10.1007/s00261-017-1157-9
14. Fouzas I, Papanikolaou C, Katsanos G, Antoniadis N, Salveridis N, Karakasi K, et al. Hepatic artery anatomic variations and reconstruction in liver grafts procured in Greece: the effect on hepatic artery thrombosis. Transplant Proc 2019; 51:416-20. doi: 10.1016/j.transproceed.2019.01.078
15. Latif A, Bangash TA, Naz S, Naseer F, Butt AK. Bilio-Vascular anatomy of Pakistani population, living donor liver transplant. Proceding SZPGMI Vol. 2016; 30:103-10.
16. Tingle SJ, Thompson ER, Ali SS, Ibrahim IK, Irwin E, Sen G, et al. Early anastomotic biliary complications after liver transplantation. Br J Surg 2021; 108:117-206. doi: 10.1093/bjs/znab117.006
17. Nakamura T, Tanaka K, Kiuhi T, Kasahra M, Oike F, Ueda M, et al. Anatomical variations and surgical strategies in right lobe living donor liver transplantation: lessons from 120 cases. Transplantation 2002; 73:1896-903. doi: 10.1097/00007890-200206270-00008
18. Hanif F, Farooq U, Malik AA, Khan A, Sayyed RH, Niazi IK. Hepatic artery variations in a sample of Pakistani population. J Coll Physicians Surg Pak 2020; 30:187-191. doi : 10.29271/jcpsp.2020.02.187
19. FONSECA-NETO OC, LIMA HC, Rabelo P, MELO PS, Amorim AG, Lacerda CM. Anatomic variations of hepatic artery: a study in 479 liver transplantations. Arq Bras Cir Dig 2017; 30:35-7. doi:10.1590/0102-6720201700010010
20. Shakeel H, Ilyas M, Butt RW, Abbas HB, Abid A, Niazi M. To determine the frequency of hepatic vein variants in normal population: role of mdct in hepatic transplantation. Pak Armed Forces Med J 2021; 71:1020-23.
21. Ahmed A, Hafeez-Baig A, Sharif MA, Ahmed U, Ahmed S, Gururajan R. Role of accessory right inferior hepatic veins in evaluation of liver transplantation. Ann Clin Gastroenterol Hepatol 2017; 1:12-6. doi: 10.29328/journal.acgh.1001004
22. Choi SH, Kim KW, Kwon HJ, Kim SY, Kwon JH, Song GW, et al. Clinical usefulness of gadoxetic acid–enhanced MRI for evaluating biliary anatomy in living donor liver transplantation. Eur Radiol 2019; 29:6508-18. doi :10.1007/s00330-019-06292-8
23. Baker TB, Zimmerman MA, Goodrich NP, Samstein B, Pomfret EA, Pomposelli JJ, et al. Biliary reconstructive techniques and associated anatomic variants in adult living donor liver transplantations: The adult-to-adult living donor liver transplantation cohort study experience. Liver Transpl 2017; 23:1519-30. doi: 10.1002/lt.24872
24. Ayoub EI, Fayed Y, Omar H, Soliman ES, Ibrahim T, Abdelkader I, et al. The impact of donor's biliary anatomy variations on the procedure of living donor liver transplantation. Egypt J Surg 2020; 39:706. doi: 10.4103/ejs.ejs_53_20
25. Cawich SO, Sinanan A, Deshpande RR, Gardner MT, Pearce NW, Naraynsingh V. Anatomic variations of the intra-hepatic biliary tree in the Caribbean: A systematic review. World J Gastrointest Endosc 2021; 13:170-83. doi : 10.4253/wjge.v13.i6.170