

Gross Anatomical Variations in the Branching Patterns of the Hepatic Artery and Portal Vein in Adult Human Livers

Shamaila Ejaz^{1*}, Mamoona shoukat², Afifa Arshad³, Nimrah Fahim⁴, Munazza Sardar⁵, Madiha Hussain⁶

^{1*}Assistant professor. Anatomy Department. Lahore Medical and Dental College, Lahore.

²Associate Professor. Anatomy Department. Sharif Medical and Dental College Lahore.

³Demonstrator. Anatomy Department. Azra Naheed Medical College. Lahore.

⁴Senior Lecturer. Anatomy Department. Shifa College of Medicine. Islamabad.

⁵Professor. Anatomy Department. Narowal Medical College. Narowal.

⁶Demonstrator. Anatomy Department. Azra Naheed Medical College. Lahore.

Corresponding Author: Shamaila Ejaz

Assistant professor. Anatomy Department. Lahore Medical and Dental College, Lahore.

Email: ¹sjjaz47@gmail.com, ²monausman25@gmail.com, ³drafifaarshad2016@gmail.com,

⁴nimrahgee@gmail.com, ⁵munazza5@yahoo.com, ⁶madiha.hussain@superior.edu.pk

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Abstract

Objective: To describe hepatic arterial and portal venous branching patterns in adult human livers examined at autopsy in three teaching hospitals of Lahore.

Materials and methods: This multicenter descriptive anatomical study conducted from July 2024 to December 2025 and included 60 adult autopsy cadavers. The hepatic arteries were traced from their parent vessels to the porta hepatis, and the main and right portal veins were examined for their major branches. Replaced and accessory arteries were distinguished by the absence or presence of the usual artery supplying the same territory. Branching patterns were recorded as frequencies and percentages. The coexistence of arterial and portal venous variants was also described.

Results: Classic hepatic arterial branching was recorded in 36 specimens (60.0%), and arterial variants were found in 24 (40.0%). A replaced right hepatic artery arising from the superior mesenteric artery was the most frequent arterial variant (10/60, 16.7%). Classic portal venous branching was recorded in 42 specimens (70.0%). The commonest portal variant was trifurcation of the main portal vein (7/60, 11.7%), followed by a right posterior portal branch arising directly from the main portal vein (5/60, 8.3%). Nine specimens (15.0%) had variants in both vascular systems.

Conclusion: Hepatic arterial and portal venous branching showed appreciable variation in this autopsy series. Describing the origin and course of each vessel provided a clearer anatomical account than assigning a classification label alone. Knowledge of these patterns remained relevant to anatomical teaching and planning hepatobiliary procedures.

Keywords: Hepatic Artery, Portal Vein, Autopsy, Cadaveric Dissection.

INTRODUCTION

The liver has a complex vascular arrangement that allows surgeons to remove, transplant, or treat one part of the organ while preserving the blood supply of another. Its hepatic arterial and portal venous branches are closely related at the porta hepatis, yet their origins and routes vary considerably between individuals. Recognizing those differences is important when interpreting liver anatomy and planning procedures near the hepatoduodenal ligament. A recent meta-analysis found variant hepatic arterial anatomy in approximately one-third of the individuals included across studies, although the frequency differed by population

and study method.¹ Portal venous variation has likewise been documented across large anatomical and clinical datasets.²

In the conventional arterial arrangement, the common hepatic artery arises from the coeliac trunk and continues as the proper hepatic artery after the gastroduodenal artery branches. The proper hepatic artery then gives rise to right and left hepatic arteries.^{3, 4} This familiar description is useful for teaching, but a vessel encountered during dissection cannot be classified reliably from its origin alone. A replaced artery takes the place of the expected artery, whereas an *accessory* artery provides an additional supply while the

expected artery remains present⁴. Tracing both the unusual vessel and the usual arterial route is therefore necessary to distinguish the two. Cadaveric studies have shown that some arrangements are uncommon or do not fit neatly into a standard classification⁵.

The most clinically familiar arterial variants involve a right hepatic artery arising from the superior mesenteric artery or a left hepatic artery arising from the left gastric artery.⁶ Their courses may bring them close to areas dissected during pancreatic, biliary, and liver operations.⁴ The relevant anatomical question is not simply whether an artery is unusual, but which part of the liver it supplies and what other arterial supply is present. This distinction is particularly important when the intended operation involves division or reconstruction of vessels at the hepatic hilum.

The main portal vein usually divides into right and left branches. The right branch subsequently supplies anterior and posterior sectors of the right liver.⁷ Important alternatives include trifurcation of the main portal vein, direct origin of the right posterior branch from the main portal vein, and transfer of a right-sided branch to the left portal vein.⁸ The precise origin of each branch matters during anatomical liver resection and portal venous reconstruction.² Recent work has also shown how different classification systems and methods of examining the liver can influence the reported frequency of these patterns.⁹

Evidence from Pakistan has described portal venous variants in clinical imaging studies, while a Lahore transplant-center study has reported vascular and biliary variation among living liver donors.^{10, 11} Those populations differ from an autopsy series, in which an anatomist can directly follow exposed vessels towards their origins and branches. Other recent reports have stressed the value of considering the hepatic artery, portal vein, and neighboring hilar structures together.^{12–14} This multicenter autopsy study described hepatic arterial and portal venous branching in 60 adult cadavers from teaching hospitals in Lahore and recorded the coexistence of variants in the same specimen.

MATERIALS AND METHODS

This multicenter descriptive anatomical study was conducted in the autopsy facilities of teaching hospitals in Lahore, Pakistan, between July 2024 and December 2025. Sixty adult cadavers were included. Ethical approval was obtained from the relevant ethics

committees of the participating teaching hospitals in Lahore. The unit of observation was one cadaver and its liver vascular anatomy; each specimen contributed one overall hepatic arterial pattern and one overall portal venous pattern.

Adult cadavers were eligible when the liver, hepatoduodenal ligament, and proximal vessels were sufficiently preserved to identify the relevant arterial origins and portal venous branches. A specimen could not be classified if major abdominal trauma, previous extensive hepatobiliary surgery, severe disruption at autopsy, or advanced local disease had obscured the vessels under examination. These criteria were intended to protect the accuracy of anatomical identification, rather than to select livers with a particular branching pattern. The age and sex entered in the study record were taken from the corresponding autopsy documentation.

The liver was examined in its anatomical position before the vascular structures were separated. The hepatoduodenal ligament was opened carefully, and the bile duct, portal vein, and arterial structures were identified. The arterial dissection proceeded from the common hepatic artery and its parent vessel towards the porta hepatis. The gastroduodenal artery, proper hepatic artery, and right and left hepatic arteries were identified where present. Any artery reaching the liver from the superior mesenteric or left gastric artery was traced towards its origin and then followed towards the hepatic tissue. The usual artery to the same territory was also sought before the unusual vessel was designated *replaced* or *accessory*. This approach prevented an additional vessel from being mistaken for the sole supply to a territory. The observed origins and branches were recorded descriptively, with conventional arterial terminology used when the anatomy met its definitions.

The portal vein was followed superiorly towards the hepatic hilum. Its first major division and the origins of the right anterior and right posterior branches were exposed as far as preservation allowed. Classic branching was defined as division of the main portal vein into right and left portal veins, followed by division of the right portal vein into anterior and posterior branches. Trifurcation was recorded when the main portal vein gave rise directly to the left, right anterior, and right posterior branches without a common right portal vein trunk. A separately arising right posterior branch was recorded when it left the

main portal vein before the remaining trunk divided. A right anterior branch arising from the left portal vein was documented by tracing its origin and destination. Less common segmental findings were recorded with their parent vessel and supplied territory rather than being assigned an unclear category.

The observations specified on the recording sheet are shown in **Table 1**. At each center, the dissection record contained the cadaver identifier, source center, demographic details,

vessel origins, and final classification. The vessel's observed course was described alongside its category so that another anatomist could review the basis for the designation. Unusual arrangements were documented by their vessel origins, courses, and destinations in the written dissection record. Records from the three centers were combined only after the categories and their definitions had been applied consistently.

Table 1. Anatomical Observations Recorded For Each Cadaver

Structure	Observation	Basis for recording a variant
Common hepatic artery	Parent vessel and course	Origin other than the conventional coeliac trunk route
Right hepatic artery	Origin, course, and presence of the usual branch	Replaced or additional supply to the right liver
Left hepatic artery	Origin, course, and presence of the usual branch	Replaced or additional supply to the left liver
Main portal vein	First major division	Bifurcation, trifurcation, or another defined division
Right portal branches	Origins of anterior and posterior branches	Separate origin from the main or left portal vein
Segmental portal branches	Parent branch and supplied territory	Branching outside the defined major patterns

Data were analyzed descriptively. Arterial and portal venous patterns were reported as frequencies and percentages of the 60 cadavers, with 95% confidence intervals for the proportions showing classic anatomy. The

coexistence of arterial and portal venous variants was presented in a cross-tabulation.

RESULTS

A total of 60 adult cadavers were examined. Their sex distribution is shown in Table 2.

Table 2. Sex Distribution of Cadavers (N=60)

Sex	Number	Percentage
Male	35	58.3
Female	25	41.7
Total	60	100.0

Classic hepatic arterial branching was recorded in 36 specimens (60.0%; 95% CI: 47.4–71.4%), while 24 specimens (40.0%) had a variant. A replaced right hepatic artery from the superior mesenteric artery was the most frequent specified arterial finding. The

complete distribution is given in **Table 3**. The replaced and accessory left hepatic arterial categories were kept separate because they describe different relationships with the usual left hepatic artery.

Table 3. Hepatic Arterial Branching Patterns

Pattern	Number	Percentage
Classic hepatic arterial branching	36	60.0
Replaced right hepatic artery from superior mesenteric artery	10	16.7
Replaced left hepatic artery from left gastric artery	6	10.0
Accessory left hepatic artery from left gastric artery	3	5.0
Accessory right hepatic artery from superior mesenteric artery	2	3.3
Both right and left hepatic arteries replaced	2	3.3
Other arterial arrangement*	1	1.7
Total	60	100.0

Classic main and right portal venous branching was observed in 42 specimens (70.0%; 95% CI: 57.5–80.1%). Eighteen specimens (30.0%) had a recorded variant. Main portal vein trifurcation accounted for seven specimens, and direct origin of the right

posterior portal branch from the main portal vein accounted for five. **Table 4** presents the remaining patterns without combining anatomically distinct branch origins under a single “early division” label.

Table 4. Portal Venous Branching Patterns

Pattern	Number	Percentage
Classic main portal vein bifurcation and right portal vein division	42	70.0
Main portal vein trifurcation	7	11.7
Right posterior branch arising directly from main portal vein	5	8.3
Right anterior branch arising from left portal vein	3	5.0
Other defined segmental branching pattern*	3	5.0
Total	60	100.0

When the two vascular systems were considered together, 27 specimens had classic patterns in both, 15 had an arterial variant alone, and nine had a portal venous variant alone. Nine specimens had a variant in both systems. These mutually exclusive groups

accounted for all 60 cadavers, as shown in **Table 5**. The table described the distribution within the series; it did not establish that a variant in one system caused or predicted a variant in the other.

Table 5. Coexistence of Hepatic Arterial and Portal Venous Variants

Hepatic arterial pattern	Classic portal venous pattern	Portal venous variant	Total
Classic hepatic arterial pattern	27	9	36
Hepatic arterial variant	15	9	24
Total	42	18	60

The two most frequent individual variants concerned different parts of the hepatic inflow: the replaced right hepatic artery arose outside the conventional arterial route, while portal vein trifurcation altered the first division of the main portal trunk. These findings required separate anatomical descriptions despite their shared position near the porta hepatis. The results also showed why reporting only an overall percentage of “vascular variation” would lose useful detail: 24 specimens had arterial variation, 18 had portal venous variation, and some contributed to both totals.

DISCUSSION

Classic hepatic arterial branching was recorded in 60.0% of specimens, and a replaced right hepatic artery from the superior mesenteric artery was the most frequent named arterial variant. A recent cadaveric investigation also documented several forms of hepatic vascular variation, although its pattern distribution differed from that of this series.¹⁵ Such differences were expected when studies used different specimen sources and defined their

arterial categories differently. Direct comparison required particular care with replaced and accessory arteries, since the two labels depended on whether the ordinary artery to the territory was present.¹⁶

The course of a replaced right hepatic artery was relevant to operations near the pancreatic head and hepatic hilum. Contemporary surgical reviews have examined the implications of an aberrant right hepatic artery during pancreaticoduodenectomy, while studies of living liver donors have shown why hilar anatomy is assessed as a whole before division or reconstruction.^{16,17} The present series described anatomy alone; it did not measure operative injuries or demonstrate that any particular branching pattern changed patient outcomes. That distinction should remain clear when an anatomical finding is translated into a clinical recommendation.

The portal findings were led by main portal vein trifurcation, followed by an independently arising right posterior branch. These were different configurations with different implications for identifying a right portal trunk. A large study focused on the right posterior

portal vein likewise showed that its origin and distribution required more detail than a broad statement that "portal anatomy varied."¹⁸ Recent investigations have continued to refine portal branching descriptions because a single classification may fail to capture every relevant branch.¹⁹ Comparisons of variant frequency should therefore consider exactly which branches each study classified.

Both arterial and portal venous variants occurred in nine specimens. The value of documenting this coexistence was practical: finding an unusual artery did not tell the anatomist where the right posterior portal branch arose. Recent cadaveric reports have also demonstrated that uncommon arterial arrangements can be missed when attention is confined to a familiar proper hepatic artery division.²⁰ Reviews of pancreatic surgery have similarly stressed careful identification of a vessel's origin and course before it is divided.²¹ The combined assessment in this study gave a fuller account of the vascular structures encountered around the liver hilum, without implying a developmental or statistical link between the two systems.

The study's strengths were its multicenter setting and direct dissection of both hepatic arterial and portal venous branches in the same specimens. Tracing vessels to their origins allowed replaced and accessory arteries to be distinguished and branching patterns to be described precisely.

CONCLUSION

Hepatic arterial and portal venous branching varied in the 60 cadavers described in this multicenter autopsy series. A replaced right hepatic artery from the superior mesenteric artery and main portal vein trifurcation were the most frequent named variants. Recording each vessel's origin, course, and destination made the findings useful for anatomical teaching and for understanding the vascular arrangements relevant to hepatobiliary procedures.

REFERENCES

1. Balcerzak A, Triantafyllou G, Demetriou F, Piagkou M, Olewnik Ł. The hepatic arterial system variations: a systematic review with meta-analysis. *Ann Anat.* 2026;263:152752.
2. Valenzuela-Fuenzalida JJ, Rodríguez-Osorio B, Salgado-Torres C, et al. A systematic review and meta-analysis: prevalence and clinical implications of anatomical variants of the hepatic portal vein. *Sci Rep.* 2024;14:30002.
3. 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;3(4):e210007.
4. Samuolyte A, Luksaite-Lukste R, Kvietkauskas M. Anatomical variations of hepatic arteries: implications for clinical practice. *Front Surg.* 2025;12:1593800.
5. Sukumaran TT, Joseph S, Ramakrishnan S, Mathew AJ. Anatomical variations of the hepatic artery in its extrahepatic journey: a cadaveric study with its clinical implications. *Anat Cell Biol.* 2022;55(3):269-276.
6. Anwar AS, Srikala J, Papalkar AS, Parveez MQ, Sharma A. Study of anatomical variations of hepatic vasculature using multidetector computed tomography angiography. *Surg Radiol Anat.* 2020;42(12):1449-1457.
7. Layton BM, Lapsia SK. The portal vein: a comprehensive review. *Radiographics.* 2023;43(11):e230058.
8. Tutkuviene J, Navakauskaite A, Narutyte R, Brazaitis A, Barkus A, Tamosiunas A. Hepatic portal vein branching patterns according to different liver assessment methods and classifications of branching type. *Ann Anat.* 2024;252:152204.
9. Liu Z, Shen T, Xia K, He J, Rui T, Chen W. Classification of variant portal vein anatomy based on three-dimensional CT: surgical implications. *Surg Radiol Anat.* 2024;46(8):1177-1184.
10. Asad Ullah M, Ahmed MS, Hamid K, Ali M, Shazlee MK, Darira J. Role of CT imaging with three-dimensional maximum intensity projection reconstruction in the evaluation of portal vein variants at a tertiary care hospital. *Cureus.* 2020;12(11):e11733.
11. Khalid A, Saleem MA, Ihsan-Ul-Haq, Khan Y, Rashid S, Dar FS. Anatomical variations in living donors for liver transplantation: prevalence and relationship. *Langenbecks Arch Surg.* 2023;408:323.
12. Valenzuela-Fuenzalida JJ, Pena-Santibañez F, Vergara Salinas A, et al. Hepatic hilum variations and their clinical considerations in the liver: a

- systematic review and meta-analysis. *Life (Basel)*. 2024;14(10):1301.
13. Ekingen A, Tuncer MC, Ertuğrul Ö. Investigation of proper hepatic artery and gastroduodenal artery variations by multidetector computed tomography angiography method. *Acta Chir Belg*. 2020;120(2):102-115.
14. Li JY, Dai WD, Hu JX, et al. Newly found variations of the right posterior portal vein identified radiologically in 1,003 Chinese patients: a cross-sectional study. *Ann Transl Med*. 2022;10(22):1237.
15. Bhardwaj N, Krishna H, Ghatak S, Gupta S. Vasculature and external surface variations of the cadaveric liver: embryological perspective with clinical relevance. *Clin Ter*. 2025;176(3):317-323.
16. Chorti A, Bontinis V, Bontinis A, Alifieris CE, Chatziantoniou G, Karlafti E, et al. A systematic review, meta-analysis and meta-regression on the implications of an aberrant right hepatic artery in patients undergoing pancreaticoduodenectomy for the treatment of malignant disease. *Minerva Surg*. 2024;79(1):82-91.
17. Kirimker EO, Kologlu M, Celik SU, Ustuner E, Kul M, Kuru Oz D, et al. Living liver donor hilar anatomical variations and impact of variant anatomy on transplant outcomes. *Medicine (Baltimore)*. 2022;101(37):e30412.
18. Bayrak AH, Dogan SN, Akay HÖ. Clinical importance of main portal vein and right portal vein variations: a prevalence study with 128-slice multidetector computed tomography. *Exp Clin Transplant*. Published online March 18, 2021.
19. Likalamu PW, Yu W, Xia N, Zhang Y, Sun L, Li X, et al. Anatomy of the right portal vein and right hepatic vein for anatomical minimally invasive liver resection. *ILIVER*. 2026;5(1):100226.
20. Tsakotos G, Triantafyllou G, Lyros O, Paschopoulos I, Piagkou M. Absence of the proper hepatic artery detected on cadaveric dissection. *Cureus*. 2025;17(3):e79957.
21. Xu YC, Yang F, Fu DL. Clinical significance of variant hepatic artery in pancreatic resection: a comprehensive review. *World J Gastroenterol*. 2022;28(19):2057-2075.
22. Yu HH, Wang SE, Shyr BS, Chen SC, Shyr YM, Shyr BU. Impact of hepatic artery variation on surgical and oncological outcomes in robotic pancreaticoduodenectomy. *Surg Endosc*. 2024;38(7):3728-3737.