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ANATOMICAL VARIATIONS OF HEPATIC ARTERIAL AND PORTAL VENOUS SYSTEM IN NORTH INDIAN CADAVERS : A CADAVERIC STUDY WITH SURGICAL CORRELATION

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ABSTRACT

Background: The clinical stakes are high in hepatobiliary surgery, liver and pancreatic operations, as well as interventional radiology, given the frequency of anatomical variations in the hepatic arterial and portal venous systems. An exact understanding of such variations is what allows for better surgical results and the avoidance of vascular damage.
Materials and Methods: We carried out a descriptive observational study on cadavers at the Department of Anatomy of the Saraswathi Institute of Medical Sciences in Hapur, Uttar Pradesh, over the period from 10th October 2024 to 31st January 2026. Standard dissection techniques were applied to 50 adult human specimens (30 of them male, 20 female) that had intact hepatobiliary anatomy. The branching and origin of the portal vein and hepatic arteries were recorded. For classification purposes, we used Michels and Hiatt for the hepatic arteries and Cheng's system for the portal vein. All data was put through SPSS version 26.0 for analysis.
Results: In 90% of the specimens (45 cases), the common hepatic artery originated from the celiac trunk, while 3 specimens (6%) and 2 specimens (4%) demonstrated an origin from the superior mesenteric artery and the left gastric artery, respectively. According to the Michels classification, 28 specimens (56%) exhibited normal Type I hepatic arterial anatomy, whereas the remaining 22 specimens (44%) showed anatomical variations. These included replaced right hepatic artery in 5 specimens (10%), replaced left hepatic artery in 5 specimens (10%), accessory right hepatic artery in 5 specimens (10%), accessory left hepatic artery in 2 specimens (4%), common hepatic artery arising from the superior mesenteric artery in 2 specimens (4%), and common hepatic artery arising from the left gastric artery in 3 specimens (6%). Regarding the portal vein, 30 specimens (60%) demonstrated the typical bifurcation pattern, while the remaining 20 specimens (40%) exhibited anatomical variations, including portal vein trifurcation in 10 specimens (20%), early branching in 8 specimens (16%), and a separate segment VI branch in 2 specimens (4%).
Conclusion: These are not uncommon findings and carry weight in any surgical or radiological context. To get the best outcome and limit complications in procedures ranging from interventional work to transplantation, it is imperative to have these vascular patterns identified before the operation. We would advocate for more extensive multicentric research to establish how prevalent these variations are across various populations.

KEYWORDS: Hepatic artery; Portal vein; Anatomical variations; Cadaveric study; Michels classification; Liver transplantation; Hepatobiliary surgery; Vascular anatomy.

INTRODUCTION

Liver is the human body's largest and most metabolically active organs, the liver is distinguished by a dual blood supply from the portal vein and the hepatic artery. The portal vein is responsible for some 70 to 75 per cent of the total hepatic flow, carrying its nutrient load from the gastrointestinal tract; the hepatic artery makes up the other 25–30 per cent while also furnishing close to half of the organ's oxygen needs. Such a vascular arrangement is indispensable for the liver to carry out its normal physiology, from detoxification to regeneration. For this reason, any surgeon, radiologist, or transplant physician engaged in hepatobiliary work must have a thorough grasp of the underlying anatomy 1.
In the classical view, the common hepatic artery comes off the celiac trunk to form the gastroduodenal artery before proceeding as the proper hepatic artery and splitting at the porta hepatis into right and left branches. On the venous side, the superior mesenteric and splenic veins join behind the pancreatic neck to create the portal vein, which then divides within the liver. Yet these are not hard and fast rules. Numerous studies have demonstrated that variations in the hepatic arterial and portal venous systems are more common than the classical anatomical pattern1,2.
The root of these variations lies in the intricacies of embryological development. In the fetus, it is the selective persistence or regression of the vitelline arteries and venous channels that sets the final architecture. Should there be any deviation in this process, one may find aberrant or accessory arteries and atypical portal branching in the adult. While such congenital differences do not typically present symptoms, they take on considerable clinical weight in the operating room during procedures like a pancreaticoduodenectomy, laparoscopic cholecystectomy or transarterial chemoembolization 3.

Hepatic arterial patterns have been well documented in the literature. Michels put forward a ten-part classification in his seminal work on 200 cadavers, a system that is still the standard. Hiatt and his team later pared this down to six categories after looking at 1,000 donor livers. Under either scheme, only 55 to 80 per cent of people will have the textbook anatomy; the rest will show anomalies, be it an accessory right hepatic artery from the superior mesenteric or a replaced left from the gastric 4,5.

There is also growing interest in the portal venous side given its bearing on resections and transplantation. Even though the majority of individuals – between 65 and 80 per cent – display normal branching, variants such as a trifurcation or early right posterior branching are not uncommon. Overlooking these in surgery can lead to everything from excessive bleeding to graft failure 6.

One cannot overstate the value of cadaveric dissection in this regard. It offers a level of direct visualization and the ability to pick out small accessory vessels or rare variants that imaging simply cannot match. In fact, what is seen in the cadaver lab is what validates the modern use of MDCT, CT angiography and 3D reconstruction in the clinic 1,7. With the rise of living donor transplants and minimally invasive techniques, knowing the anatomy beforehand is key to shortening operative time and avoiding complications 3,8.

Still, prevalence rates for these variations differ across ethnic and geographical lines, and many parts of the world are underrepresented in the existing data. This study was undertaken to fill that gap. We set out to examine the hepatic arterial and portal venous systems in cadavers to record their frequency and morphology, measure them against the classifications of Michels and Hiatt, and assess what they mean for the practice of interventional radiology and hepatobiliary surgery.

MATERIALS AND METHODS

The present study was a descriptive, observational cadaveric study conducted in the Department of Anatomy, Saraswathi Institute of Medical Sciences, Anwarpur, Hapur, Uttar Pradesh, over a period of 10th October 2024 to 31st January 2026. The study included 50 embalmed adult human cadavers of either sex with well-preserved hepatobiliary anatomy. Cadavers with previous abdominal surgery, gross congenital anomalies, trauma, or poorly preserved abdominal viscera were excluded.

The cadaveric dissections were performed using the standard techniques described in Cunningham's Manual of Practical Anatomy. The abdominal cavity was opened through a midline incision, and careful dissection was carried out to expose the celiac trunk, common hepatic artery, proper hepatic artery, portal vein, and their branches. The origin, course, branching pattern, and anatomical variations of the hepatic arteries and portal vein were identified and documented. Hepatic arterial variations were classified according to the Michels and Hiatt classifications, while portal venous variations were recorded according to standard anatomical classifications.

The findings were documented using a predesigned data collection proforma and digital photographs wherever necessary. The collected data were entered into Microsoft Excel and analyzed using SPSS version 26.0.

RESULTS

Our study was performed on 50 cadavers of known sex, comprising 30 males and 20 females.

Table 1. Origin of the Common Hepatic Artery (n = 50)

Origin of Common Hepatic Artery	Frequency (n)	Percentage (%)
Celiac Trunk (CT)	45	90.0
Superior Mesenteric Artery (SMA)	3	6.0
Left Gastric Artery (LGA)	2	4.0
Total	50	100.0

The common hepatic artery originated from the celiac trunk in 45 (90.0%) specimens. Variations were observed in 5 (10.0%) specimens, with the common hepatic artery arising from the superior mesenteric artery in 3 (6.0%) specimens and from the left gastric artery in 2 (4.0%) specimens.

Table 2. Michels Classification of Hepatic Arterial Variations (n = 50)

Michels Type	Description	Frequency (n)	Percentage (%)
Type I	Normal hepatic arterial anatomy	28	56.0
Type II	Replaced left hepatic artery from LGA	5	10.0
Type III	Replaced right hepatic artery from SMA	5	10.0
Type V	Accessory left hepatic artery from LGA	2	4.0
Type VI	Accessory right hepatic artery from SMA	5	10.0
Type IX	Common hepatic artery from SMA	2	4.0
Type X	Common hepatic artery from LGA	3	6.0
Total		50	100.0

According to the Michels classification, Type I (normal hepatic arterial anatomy) was the most common pattern, observed in 28 (56.0%) specimens. Variations were present in 22 (44.0%) specimens, including Type II, III, and VI in 5 (10.0%) specimens each, Type V in 2 (4.0%) specimens, Type IX in 2 (4.0%) specimens, and Type X in 3 (6.0%) specimens.

Table 3. Origin of the Right Hepatic Artery (n = 50)

Origin of Right Hepatic Artery	Frequency (n)	Percentage (%)
Proper Hepatic Artery (PHA)	38	76.0
Superior Mesenteric Artery (SMA)	12	24.0

Total	50	100.0

The right hepatic artery originated from the proper hepatic artery in 38 (76.0%) specimens. A replaced or accessory right hepatic artery arising from the superior mesenteric artery was observed in 12 (24.0%) specimens.

Table 4. Origin of the Left Hepatic Artery (n = 50)

Origin of Left Hepatic Artery	Frequency (n)	Percentage (%)
Proper Hepatic Artery (PHA)	40	80.0
Left Gastric Artery (LGA)	10	20.0
Total	50	100.0

The left hepatic artery originated from the proper hepatic artery in 40 (80.0%) specimens. A replaced or accessory left hepatic artery arising from the left gastric artery was observed in 10 (20.0%) specimens.

Table 5. Portal Vein Branching Pattern (n = 50)

Portal Vein Branching Pattern	Frequency (n)	Percentage (%)
Normal bifurcation	30	60.0
Trifurcation	10	20.0
Early branching	8	16.0
Separate Segment VI branch	2	4.0
Total	50	100.0

The normal portal vein bifurcation was the most common branching pattern, observed in 30 (60.0%) specimens. Variations were identified in 20 (40.0%) specimens, including portal vein trifurcation in 10 (20.0%), early branching in 8 (16.0%), and a separate segment VI branch in 2 (4.0%) specimens.

Table 6. Portal Vein Variation According to Cheng's Classification (n = 50)

Cheng's Classification	Description	Frequency (n)	Percentage (%)
Type I	Normal bifurcation	30	60.0
Type II	Trifurcation	10	20.0
Type III	Early branching	8	16.0
Type IV	Separate origin of right posterior segmental branch	2	4.0
Total		50	100.0

Based on Cheng's classification, Type I (normal bifurcation) was the predominant portal vein branching pattern, observed in 30 (60.0%) specimens. Type II (trifurcation) was present in 10 (20.0%) specimens, Type III (early branching) in 8 (16.0%) specimens, and Type IV (separate origin of the right posterior segmental branch) in 2 (4.0%) specimens.

Table 7. Distribution of Hepatic Arterial Variations (n = 50)

Hepatic Arterial Pattern	Frequency (n)	Percentage (%)
Normal hepatic arterial anatomy	28	56.0
Replaced right hepatic artery	5	10.0
Replaced left hepatic artery	5	10.0
Accessory right hepatic artery	5	10.0
Accessory left hepatic artery	2	4.0
Common hepatic artery arising from SMA	2	4.0
Common hepatic artery arising from LGA	3	6.0
Total	50	100.0

Normal hepatic arterial anatomy was observed in 28 (56.0%) specimens, whereas 22 (44.0%) demonstrated anatomical variations. The most frequent variants were replaced right hepatic artery, replaced left hepatic artery, and accessory right hepatic artery, each occurring in 5 (10.0%) specimens. Accessory left hepatic artery and common hepatic artery arising from the superior mesenteric artery were each observed in 2 (4.0%) specimens, while common hepatic artery arising from the left gastric artery was identified in 3 (6.0%) specimens.

DISCUSSION

A total of 50 cadavers were included in this study, comprising 30 males and 20 females. In 45 specimens (90%), the common hepatic artery (CHA) originated from the celiac trunk, whereas 5 specimens (10%) demonstrated a variant origin, including 3 specimens (6%) arising from the superior mesenteric artery (SMA) and 2 specimens (4%) from the left gastric artery (LGA). These findings are comparable to those of Ügurel et al., who reported celiac trunk trifurcation in 89% of cases and hepatic arterial variations in 48% 7. However, the 6% incidence of CHA originating from the SMA observed in the present study is higher than the 1.5% reported by Hiatt et al. (15/1000 cases) 4.

According to the Michels classification, Type I (normal hepatic arterial anatomy) was identified in 28 specimens (56%). This closely approximates the classical Michels description, in which Type I anatomy is present in approximately 55% of individuals 3. However, it remains lower than the 75.7% reported by Hiatt et al. 4 and the 81% reported by Noussios et al. in their review of more than 19,000 cases 1. These differences may be attributed to population characteristics, sample size, and the cadaveric nature of the present study.

Hepatic arterial variations were observed in 22 specimens (44%), which is comparable with the 48% reported by Ügurel et al. 7 and falls within the 45–75% range described by Samuolytė et al. 12, although it remains higher than the 24.3% reported by Hiatt et al. 4

A replaced right hepatic artery arising from the SMA was observed in 5 specimens (10%), exceeding the 3.7% reported by Noussios et al. 1, but closely matching the 10.6% frequency of replaced or accessory right hepatic arteries arising from the SMA reported by Hiatt et al.4 Similarly, an accessory right hepatic artery originating from the SMA was identified in 5 specimens (10%), compared with the 1.6% reported by Noussios et al.1

Regarding the left hepatic artery, a replaced left hepatic artery arising from the LGA was identified in 5 specimens (10%), while an accessory left hepatic artery was observed in 2 specimens (4%). These values are higher than the 3% and 3.2%, respectively, reported by Noussios et al.1 Hiatt et al.4 reported a combined incidence of 9.7% for replaced and accessory left hepatic arteries, which is similar to the findings of the present study.

Less common variations were also encountered. Two specimens (4%) demonstrated a common hepatic artery arising from the SMA (Michels Type IX), whereas three specimens (6%) showed a common hepatic artery arising from the LGA (Type X) 3. Noussios et al.1 described these variants as rare but clinically significant, while Hiatt et al.4 reported a frequency of only 1.5% for the common hepatic artery originating from the SMA. Although these uncommon variants appeared more frequently in the present study, the relatively modest sample size of 50 cadavers may partly explain these differences. Our findings also contrast with those of Sukumaran et al., who reported hepatic arterial variations in only 8.5% (3/35) of cadavers8, whereas the present study demonstrated variations in 44% of specimens. Such differences may reflect variations in study populations, sample size, and the criteria used to classify replaced and accessory arteries.

Asif et al. emphasized the clinical significance of hepatic arterial variants, particularly replaced hepatic arteries arising from the SMA or LGA, during hepatobiliary surgical procedures 9. Although their report was based on isolated cases, it highlights the surgical importance of the variations documented in the present study. In 38 specimens (76%), the right hepatic artery originated from the proper hepatic artery, whereas 12 specimens (24%) demonstrated a replaced or accessory right hepatic artery arising from the superior mesenteric artery (SMA). Similarly, the left hepatic artery originated from the proper hepatic artery in 40 specimens (80%), while 10 specimens (20%) exhibited a replaced or accessory left hepatic artery arising from the left gastric artery (LGA). These observations confirm the SMA and LGA as the predominant alternative sources of the right and left hepatic arteries, respectively, in agreement with previous anatomical and radiological studies 2,6,7,12. Considerable variation was also observed in portal vein branching. Normal portal vein bifurcation was present in 30 specimens (60%), while the remaining 20 specimens (40%) exhibited variant branching patterns. This proportion of normal bifurcation is lower than that reported by Cheng et al. in studies of living donor liver transplantation 10 and also lower than the anomaly rate of approximately 25% described by Katsourakis et al. 11.

Portal vein trifurcation was identified in 10 specimens (20%), a value exceeding the 9.6% reported by Katsourakis et al. 11 but closely corresponding to the 21.7% frequency of Cheng Type II branching reported by Cheng et al. 10. Early branching was observed in 8 specimens (16%), while a separate segment VI (right posterior segmental) branch was identified in 2 specimens (4%). The incidence of the latter is comparable to the 5.7% reported by Cheng et al., whereas the frequency of early branching is slightly higher than the 8.2% reported by Katsourakis et al. 11.

Overall, the present study demonstrates that anatomical variations of both the hepatic arterial and portal venous systems are common. The 44% prevalence of hepatic arterial variations is comparable to the findings reported by Ügurel et al. 7 and Samuolytė et al. 12. Likewise, the 40% prevalence of portal vein variations is higher than that reported in many radiological studies 5,10,11, although the overall distribution remains similar, with normal bifurcation representing the predominant pattern followed by trifurcation and early branching. Recognition of these anatomical variations is essential for hepatobiliary surgery, liver transplantation, pancreatic surgery, laparoscopic cholecystectomy, gastrectomy, and interventional radiological procedures, where detailed preoperative anatomical knowledge contributes to reducing vascular complications and improving surgical outcomes 1,2,11,12.

CONCLUSION

This cadaveric work has shown the clinical significance of, and commonality in, anatomical variations of the hepatic arterial and portal venous systems. Of the specimens examined, 55% had normal hepatic arterial anatomy; the remaining 45% presented with variations, most often in the form of replaced or accessory right and left hepatic arteries stemming from the superior mesenteric or left gastric artery. We also came across some rarer forms, such as a common hepatic artery with its origin in either of those two vessels.

In terms of the portal vein, 40% of the cases displayed variations, trifurcation and early branching being the predominant types once one moves past the standard bifurcation. While these results are in line with what has been put forward in earlier radiological and anatomical literature, we did see a higher incidence of certain variations in our series, which can be put down to population differences and the constraints of the sample size.

For interventional radiologists, transplant teams and surgeons working on hepatobiliary, pancreatic or liver transplant cases, an awareness of these vascular idiosyncrasies is key to avoiding postoperative complications or any chance of vascular injury. The study would have one make use of modern imaging for a complete preoperative evaluation and to be well versed in the subject matter. To put the clinical applicability of these findings on firmer ground and get a more precise handle on their prevalence, it is advisable that future research be of a multicentric nature with larger and more varied populations.

REFERENCES

1. Noussios G, Dimitriou I, Chatzis I, Katsourakis A. The main anatomic variations of the hepatic artery and their importance in surgical practice: review of the literature. J Clin Med Res. 2017;9(4):248–252.
2. Malviya KK, et al. Importance of anatomical variation of the hepatic artery for hepatobiliary pancreatic surgery and liver transplantation. Diagnostics (Basel). 2023;13:1233.
3. Michels NA. Newer anatomy of the liver and its variant blood supply and collateral circulation. Am J Surg. 1966;112(3):337–347.
4. Hiatt JR, Gabbay J, Busuttil RW. Surgical anatomy of the hepatic arteries in 1000 cases. Ann Surg. 1994;220(1):50–52.
5. Covey AM, Brody LA, Getrajdman GI, Sofocleous CT, Brown KT. Incidence, patterns, and clinical relevance of variant portal vein anatomy. AJR Am J Roentgenol. 2004;183(4):1055–1064.
6. Bolintineanu LA, et al. Clinical consideration of anatomical variations in the common hepatic arteries: an analysis using MDCT angiography. Diagnostics (Basel). 2023;13:1636.
7. Ügurel MS, Battal B, Bozlar U, Nural MS, Tasar M, Ors F, et al. Anatomical variations of hepatic arterial system, coeliac trunk and renal arteries: an analysis with multidetector CT angiography. Br J Radiol. 2010;83(992):661–667.
8. Sukumaran TT, Sreejith S, Radhakrishnan P, et al. Anatomical variations of the hepatic artery in its extrahepatic course: a cadaveric study. Cureus. 2022;14(9):e29670.
9. Asif M, Aamir S, Khan MA, et al. Replaced right and left hepatic arteries: a rare anatomical variation and its clinical significance. Case Rep Surg. 2017;2017:1–4.
10. Cheng YF, Huang TL, Chen CL, Chen TY, Lee TY. Variations of the intrahepatic portal vein: angiographic demonstration and application in living-related hepatic transplantation. Transplant Proc. 1996;28(3):1667–1668.
11. Katsourakis A, Noussios G, Chatzitheoklitos E, et al. Anatomy of the portal venous system: a review of the literature. Surg Radiol Anat. 2011;33(5):375–381.
12. Samuolytė J, et al. Anatomical variations of hepatic arteries: implications for surgery. Front Surg. 2025;12:1593800.