Original Research

STUDY OF ANATOMICAL VARIATIONS OF THE HEPATIC ARTERY IN HUMAN CADAVERS

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ABSTRACT

Background: The hepatic artery is the principal arterial supply to the liver and exhibits considerable anatomical variation. Knowledge of these variations is essential for hepatobiliary surgeries, liver transplantation, radiological interventions, and laparoscopic procedures to prevent vascular injury and postoperative complications. Cadaveric evaluation of hepatic arterial anatomy provides valuable information regarding branching patterns and uncommon variants that may influence surgical planning and clinical outcomes.

Aims: To study the anatomical variations in the origin, course, and branching pattern of the hepatic artery in human cadavers and to determine the frequency of common and variant hepatic arterial anatomy.

Materials and Methods: This descriptive cadaveric study was conducted in the Department of Anatomy over a period of 10 months. A total of 40 adult human cadavers were included in the study. Cadavers with intact hepatobiliary and abdominal vascular anatomy were selected for dissection. Detailed abdominal dissection was performed to expose the celiac trunk, common hepatic artery, proper hepatic artery, and their branches. Variations in origin, branching pattern, accessory or replaced hepatic arteries, and arterial course were carefully identified and documented. Morphometric observations were recorded and analyzed using descriptive statistical methods.

Results: Among the 40 cadavers studied, classical hepatic arterial anatomy was observed in 28 (70.0%) specimens, while variations were identified in 12 (30.0%) cadavers. The most common variation was replaced right hepatic artery arising from the superior mesenteric artery, observed in 5 (12.5%) specimens. Accessory left hepatic artery arising from the left gastric artery was identified in 3 (7.5%) cadavers. Replaced left hepatic artery originating from the left gastric artery was observed in 2 (5.0%) specimens, while accessory right hepatic artery was present in 1 (2.5%) specimen. Common hepatic artery arising directly from the abdominal aorta was identified in 1 (2.5%) cadaver.

Conclusion: The hepatic artery demonstrates significant anatomical variation in origin and branching pattern. Classical anatomy was present in the majority of cadavers. Awareness of these variations is essential for surgeons, anatomists, and interventional radiologists to minimize operative complications and improve outcomes during hepatobiliary procedures and liver transplantation.

Keywords: Accessory Hepatic Artery, Cadaver, Common Hepatic Artery, Hepatic Artery, Liver Transplantation, Replaced Hepatic Artery, Vascular Variations.

INTRODUCTION

The liver is one of the most vascular and metabolically active organs in the human body, receiving dual blood supply from the portal vein and hepatic artery.[1] the hepatic artery is responsible for supplying oxygenated blood to the liver, biliary apparatus, gallbladder, and portions of the stomach and pancreas.[2]

www.ajmrhs.com
eISSN: 2583-7761

Date of Received: 13-05-2026
Date Acceptance: 19-05-2026
Date of Publication: 30-06-2026

Normally, the common hepatic artery arises from the celiac trunk and courses toward the liver, giving rise to the gastroduodenal artery before continuing as the proper hepatic artery, which further divides into right and left hepatic arteries. Although this classical arterial pattern is commonly described in anatomical textbooks, numerous variations in origin, branching pattern, and course of the hepatic artery have been documented.[3,4]

Surgical procedures such as liver transplantation, hepatic resections, pancreaticoduodenectomy, laparoscopic cholecystectomy, and transarterial chemoembolization require precise understanding of hepatic vascular anatomy. Failure to recognize vascular variations may result in accidental ligation, ischemic complications, uncontrolled hemorrhage, biliary necrosis, or graft failure during transplantation.[5]

Variations in hepatic arterial anatomy occur due to developmental alterations during embryogenesis. During fetal life, the liver develops vascular connections from multiple ventral splanchnic branches arising from the abdominal aorta.[6] Persistence or regression of these embryonic vessels leads to formation of accessory or replaced hepatic arteries. The right hepatic artery may arise from the superior mesenteric artery, while the left hepatic artery may originate from the left gastric artery.[7] In some individuals, the common hepatic artery may arise directly from the abdominal aorta or superior mesenteric artery. Such variations are clinically significant because they may alter the vascular supply to the liver and surrounding organs.[8]

Detailed anatomical dissection helps identify uncommon branching patterns that may not always be appreciated through imaging studies alone. Information obtained from cadaveric observations assists surgeons, anatomists, and radiologists in correlating anatomical findings with operative and radiological procedures.[9] additionally, morphometric analysis of hepatic arteries contributes to improved preoperative planning and reduction of surgical complications.[10]

The increasing frequency of minimally invasive hepatobiliary procedures and liver transplantation has renewed interest in studying hepatic arterial anatomy. Despite numerous anatomical studies, regional differences in vascular anatomy continue to be reported, emphasizing the need for population-specific cadaveric evaluation. Identification of accessory and replaced hepatic arteries may improve preoperative planning, reduce intraoperative vascular injury, and enhance surgical safety during liver transplantation, pancreatic surgery, and interventional radiological procedures.

Aims and Objectives

- To study the anatomical variations in the origin, course, and branching pattern of the hepatic artery in human cadavers
- To determine the frequency of common and variant hepatic arterial anatomy.

MATERIALS AND METHODS

The present descriptive cadaveric study was conducted in the Department of Anatomy at Sree Mookambika Institute of Medical Sciences over a period of 10 months from June 2025 to March 2025. A total of 40 adult human cadavers available in the Department of Anatomy were included in the study. Cadavers were carefully selected for detailed dissection and evaluation of hepatic arterial anatomy.

Inclusion Criteria

- Adult human cadavers with intact abdominal viscera and vascular anatomy.
- Well-embalmed cadavers suitable for detailed abdominal dissection.
- Cadavers without evidence of prior hepatobiliary surgical intervention.
- Cadavers with preserved celiac trunk and hepatic arterial system.

Exclusion Criteria

- Cadavers with damaged or disrupted abdominal vascular anatomy.
- Cadavers with previous abdominal or hepatobiliary surgery altering arterial anatomy.
- Pediatric cadavers.
- Poorly embalmed or decomposed cadavers unsuitable for dissection.
- Cadavers with traumatic injury involving the upper abdominal region.

Routine dissection of the abdominal cavity was performed according to standard anatomical procedures. The anterior abdominal wall was opened and abdominal viscera were exposed. The stomach, liver, pancreas, duodenum, and associated peritoneal structures were carefully dissected to identify the celiac trunk and its branches. The common hepatic artery, proper hepatic artery, right and left hepatic arteries, gastroduodenal artery, and accessory or replaced hepatic arteries were meticulously traced from their origin to their termination.

Variations in origin, branching pattern, course, and distribution of hepatic arteries were observed and documented. Particular attention was given to the presence of accessory hepatic arteries, replaced hepatic arteries, anomalous origin of common hepatic artery, and unusual branching patterns.

Measurements related to the course and branching of hepatic arteries were recorded using standard dissection instruments and measuring scales wherever required. Photographic documentation of important anatomical variations was performed for academic and reference purposes. All findings were tabulated and classified according to standard anatomical descriptions and commonly accepted hepatic arterial classification patterns. The observed variations were analysed descriptively and expressed in percentages and frequencies.

The collected data were entered in Microsoft Excel and analysed using Statistical SPSS version 25.0. Descriptive statistical methods such as frequency, percentage, mean, and standard deviation were used to summarize the findings. Variations in hepatic arterial anatomy were expressed as proportions and analyzed using appropriate statistical methods.

OBSERVATION AND RESULTS

A total of 40 cadavers were studied to evaluate variations in hepatic arterial anatomy. Classical hepatic arterial anatomy was observed in 28 (70.0%) cadavers, whereas anatomical variations were identified in 12 (30.0%) specimens. The findings indicate that nearly one-third of individuals may demonstrate altered hepatic arterial patterns,

emphasizing the surgical importance of preoperative vascular assessment. (Table 1)

Parameter	Number (N=40)	Percentage (%)
Male Cadavers	28	70.0
Female Cadavers	12	30.0
Classical Hepatic Artery Anatomy	28	70.0
Variant Hepatic Artery Anatomy	12	30.0

Table 1: Distribution of Cadavers According to Side and Presence of Hepatic Artery Variations

The most common variation observed was replaced right hepatic artery arising from the superior mesenteric artery, identified in 5 (12.5%) cadavers. Variations involving the left hepatic artery were comparatively less frequent, while anomalous origin of the common hepatic artery was rare. (Table 2)

Table 2: Types of Hepatic Artery Variations Observed

Type Of Variation	Number (N=40)	Percentage (%)
Replaced Right Hepatic Artery From SMA	5	12.5
Accessory Left Hepatic Artery From Left Gastric Artery	3	7.5
Replaced Left Hepatic Artery From Left Gastric Artery	2	5.0
Accessory Right Hepatic Artery	1	2.5
Common Hepatic Artery From Abdominal Aorta	1	2.5
No Variation	28	70.0

Normal bifurcation of the proper hepatic artery was observed in the majority of specimens. However, trifurcation and early branching patterns were identified in 9 (22.5%) cadavers, which may increase technical difficulty during hepatobiliary and transplant procedures. (Table 3)

Table 3: Branching Pattern of Proper Hepatic Artery

Branching Pattern	Number (N=40)	Percentage (%)
Normal Bifurcation Into Right And Left Hepatic Arteries	31	77.5
Trifurcation Pattern	5	12.5
Early Branching Pattern	4	10.0

Hepatic artery variations were slightly more common among male cadavers compared to females. However, the association between gender and presence of arterial variation was not statistically significant ($p > 0.05$). (Table 4)

Table 4: Correlation between Hepatic Artery Variations and Gender

Gender	Variations Present N (%)	Variations Absent N (%)	Total N (%)	P-Value
Male	9 (32.1%)	19 (67.9%)	28 (100%)	0.62
Female	3 (25.0%)	9 (75.0%)	12 (100%)	
Total	**12 (30.0%)**	**28 (70.0%)**	**40 (100%)**	

Abnormal branching patterns were significantly associated with the presence of hepatic arterial variations ($p < 0.01$). Cadavers with replaced or accessory hepatic arteries demonstrated higher frequency of altered branching anatomy compared to specimens with classical arterial patterns. (Table 5)

Table 5: Correlation between Type of Hepatic Artery Variation and Branching Pattern

Variation Type	Abnormal Branching N (%)	Normal Branching N (%)	Total N (%)	P-Value
Replaced/Accessory Hepatic Arteries	7 (63.6%)	4 (36.4%)	11 (100%)	<0.01
Common Hepatic Artery Anomaly	1 (100%)	0 (0%)	1 (100%)	
No Arterial Variation	1 (3.6%)	27 (96.4%)	28 (100%)	
Total	**9 (22.5%)**	**31 (77.5%)**	**40 (100%)**	

Variations involving the right hepatic artery were most frequently observed, accounting for 50.0% of all variant specimens. The distribution of arterial variations according to site showed statistical significance ($p < 0.05$), indicating greater anatomical variability of the right hepatic arterial system. (Table 6)

Table 6: Correlation between Presence of Variations and Site of Arterial Involvement

Site of Variation	Number (N=12)	Percentage (%)	P Value
Right Hepatic Artery	6	50.0	0.04
Left Hepatic Artery	5	41.7	
Common Hepatic Artery	1	8.3	

DISCUSSION

A total of 40 cadavers were studied to evaluate anatomical variations of the hepatic artery. Classical hepatic arterial anatomy was observed in 28 (70.0%) specimens, while variations were identified in 12 (30.0%) cases. This overall prevalence of variations is comparable to the findings of Garg S et al.[11] who reported standard anatomy in 72% and aberrant anatomy in 28% of livers, showing a nearly similar distribution pattern and reinforcing that hepatic arterial variations are not uncommon in routine anatomical populations.

In the present study, the most frequent variation was a replaced right hepatic artery arising from the superior mesenteric artery in 5 (12.5%) cadavers, followed by accessory left hepatic artery from the left gastric artery in 3 (7.5%) and replaced left hepatic artery in 2 (5.0%). A rare case of common hepatic artery arising directly from the abdominal aorta was observed in 1 (2.5%) cadaver. These findings align with Priyadharshini S et al.[12] who reported that the right hepatic artery originated from the proper hepatic artery in 60% of cases, while aberrant, accessory, and replaced right hepatic arteries accounted for a significant proportion of variations, highlighting the predominance of right-sided variability in both studies.

The present study demonstrated that variations involving the right hepatic artery were more common than those involving the left hepatic artery, indicating greater anatomical variability on the right side. This observation is supported by Choi TW et al.[13] who reported similar prevalence of aberrant right (15.63%) and left hepatic arteries (16.32%), suggesting that although both sides show variability, right hepatic artery variations remain clinically significant and frequently encountered. Additionally, they observed a strong association between right and left hepatic artery variations, suggesting systemic vascular patterning, which complements the present study's observation of multiple coexisting variations.

Normal branching of the proper hepatic artery into right and left hepatic arteries was seen in 31 (77.5%) cadavers, while abnormal branching patterns such as trifurcation and early branching were seen in 9 (22.5%). A similar spectrum of branching complexity was described by Akpabio A et al.[14] who observed Type I as the most common pattern but also reported multiple variant types affecting branching and origin of hepatic arteries, emphasizing that even when classical anatomy predominates, significant variation persists across populations.

A statistically significant association was observed between hepatic artery variations and abnormal branching patterns ($p < 0.01$) in the present study, indicating that replaced or accessory arteries are frequently associated with altered branching architecture. Although not statistically tested in a similar manner, Khatiwada S et al.[15] described multiple origins of the middle hepatic artery from both right and left hepatic arteries in 76% of cases, demonstrating that branching variability often coexists with accessory arterial patterns, supporting the present finding of interrelated vascular variations.

Rare vascular anomalies observed in the present study, including direct origin of the common hepatic artery from the abdominal aorta, are consistent with findings of Pusala B et al.[16] who documented a replaced common hepatic artery arising from the superior mesenteric artery and classified it as Michel type IX variation. Both studies highlight the importance of recognizing rare but surgically significant deviations from classical anatomy.

Similarly, Imam a et al.[17] reported that 60.9% of donors were classified as Michel type I, while multiple replaced and accessory hepatic arteries were distributed across other types, reinforcing that classical anatomy remains predominant but with a substantial proportion of clinically relevant variants. This parallels the present study, where 70% of cases showed classical anatomy but 30% exhibited variations.

Further supporting these findings, Kobayashi S ET al.[18] demonstrated extensive variability in hepatic and related arterial patterns, with multiple previously unclassified formations and significant asymmetry in vascular structures. This broad variability complements the present study's observation that hepatic arterial anatomy is highly variable and cannot always be restricted to standard classification systems.

CONCLUSION

The study demonstrated that significant anatomical variations exist in the hepatic arterial system, with

classical anatomy observed in most of the cadavers and variations identified in a considerable proportion. Replaced and accessory hepatic arteries, particularly involving the right hepatic artery, were the most common variations encountered. Variations in branching pattern and arterial origin have important clinical implications during hepatobiliary surgeries, liver transplantation, and radiological interventions. Careful preoperative evaluation and thorough anatomical understanding of hepatic arterial variations are essential to prevent vascular injury and postoperative complications. Knowledge of these variations contributes to safer surgical practice and improved patient outcomes.

Financial Support and Sponsorship: Nil.

Conflicts Of Interest: There are no conflicts of interest

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How to cite this article: Girija Kumari K, Rathisha S, STUDY OF ANATOMICAL VARIATIONS OF THE HEPATIC ARTERY IN HUMAN CADAVERS, Asian J. Med. Res. Health Sci., 2026; 4 (2):1502-1506.
Source of Support: Nil, Conflicts of Interest: None declared.