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ANATOMICAL VARIATIONS OF HEPATIC ARTERY USING MULTIDETECTOR COMPUTED TOMOGRAPHY (MDCT) ANGIOGRAPHY

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Abstract: Background: Hepatic arterial variations are important during hepatobiliary surgery, liver transplantation, and interventional radiology. Missed variants may increase the risk of bleeding, biliary injury, hepatic ischemia, and incomplete catheter-based treatment. **Objective:** To determine the frequency of types of hepatic artery variations in patients using post-contrast abdominal multidetector computed tomography. **Methodology:** This cross-sectional study was carried out at the Department of Diagnostic Radiology, Pakistan Kidney and Liver Institute, Lahore, between 10 May 2025 and 10 November 2025. The patients involved in this study were 298 patients of both sexes aged 15-65 years who underwent abdominal CT in the arterial phase using non-probability consecutive sampling. Patients with impaired renal function, iodinated contrast allergy, previous hepatic or major abdominal surgery or pathology altering vascular anatomy were excluded. A 128-slice CT scanner was used to perform the CT angiography. Multiplanar and three dimensional reconstruction was performed and reviewed. Hepatic arterial anatomy was classified according to Michel's classification and Hiatt's classification. The SPSS version 25.0 was used for analysis of the data including standard deviation and Pearson chi square tests. **Results:** The mean age was 54.06 ± 11.59 years. Male patients were 244 (81.9%). Michel Type I anatomy was found in 220 patients (73.8%). Anomalous hepatic arterial pattern was found in 78 patients (26.2%). Michel Type III was the most common anomaly. No significant association was found with gender or age group. **Conclusion:** Normal hepatic arterial anatomy was the most frequent pattern, while Michel Type III was the commonest variant. MDCT angiography was useful for identifying hepatic arterial variations.

Keywords: Angiography; Hepatic artery; Hiatt classification; Michel classification; Multidetector computed tomography.

INTRODUCTION

The hepatic arterial anatomy is relevant to diagnostic radiology, hepatobiliary surgery, liver transplantation, and interventional procedures. Variations in the hepatic artery may affect the surgical approach and the route of catheter-based therapy. These variants can also lead to bleeding, biliary injury, hepatic ischemia, and incomplete treatment if not recognized prior to the procedure.1 The common hepatic artery is usually a branch of the coeliac trunk. It then becomes the proper hepatic artery and branches into right and left hepatic arteries. This is a normal anatomy pattern. But the right hepatic artery, left hepatic artery, or common hepatic artery may be a branch of another artery. These arteries can be replaced or accessory. Replaced arteries provide the main arterial blood to a liver segment or lobe. Additional arterial supply is provided by accessory arteries.2

Several classification systems are used to describe these variations. The common hepatic artery variants are described in detail by Michel's classification. Hiatt's classification is simpler and is commonly used in clinical and transplant-related research. These systems are still being used in recent imaging-based studies, as they enable the standard reporting of hepatic arterial anatomy.3 Hepatic arterial variations are found in different populations. This variation could be due to ethnicity, sample size, imaging technique and classification method. In a CT angiography study by Acar et al., coeliac trunk and hepatic artery variants were accurately identified and may warrant population-specific reporting.4 Another CT angiography study by Türkyılmaz et al. also revealed that common hepatic artery and coeliac artery variations are common enough to warrant careful preoperative vascular mapping.5

Multidetector computed tomography angiography is a useful non-invasive method for evaluating the hepatic arterial anatomy. It offers thin section images and enables multiplanar and 3D reconstruction. These images are helpful in identifying the origin, course, and branching pattern of the hepatic arteries. Recent studies in various populations have demonstrated that MDCT angiography is able to identify common and uncommon hepatic arterial variants.6 A recent mini-review highlighted the clinical relevance of hepatic arterial variations in hepatopancreatobiliary surgery, transplantation and interventional radiology. It also emphasized the importance of identifying arterial variants to avoid hemorrhage, ischemia, or complications during procedures. This reinforces the importance of regular and systematic reporting of hepatic arterial anatomy prior to major abdominal surgery.7

The scientific gap is that there is a lack of local data on hepatic artery variations using post-contrast abdominal MDCT. Most of the data available are from other populations. These findings may not be representative of the local population. Thus, local frequency data are required to enhance radiological reporting, surgical planning, transplant assessment and interventional decision making. The aim of this study was to identify the prevalence of hepatic artery variants in the local population by post-contrast abdominal multidetector computed tomography.

MATERIALS AND METHODS

The study was a prospective study (cross-sectional) carried out at the Department of Diagnostic Radiology, PKLI (Pakistan Kidney and Liver Institute), Lahore, from 10 May 2025 to 10 November 2025. Nevertheless, the research was done within 03 months (10 August 2025). This study was granted approval by the Institutional Review Board (IRB) of Pakistan Kidney and Liver Institute and Research Center (PKLI&RC), Lahore (IRB No. 00392025; Ref: PKLI-IRB/AP/00392025), dated 20 May 2025. Non-probability consecutive sampling was used. The size of the sample was calculated by using proportion formula of single population. The incidence of an anomalous hepatic arterial pattern was expected to be 26.2% as reported by Zaki et al. in a multidetector computed tomography angiography study of hepatic artery variations. The sample size was calculated using a 95% confidence level, 5% absolute precision, an expected proportion of 26.2%, and q = 73.8%, resulting in a sample size of 297.128,[8] which was rounded up to 298 patients.

298 patients were studied. Patients of both sexes, 15 to 65 years old, who had an arterial phase CT scan of the abdomen were included. Patients with abnormal renal function (serum creatinine >1.2 mg/dL) were excluded. Patients who had an allergy to iodinated contrast media were also excluded. Patients who had previous hepatic or extensive abdominal surgery were excluded. Patients with pathological conditions which may affect the vascular anatomy (e.g. hepatocellular carcinoma with parasitic arterial flow) were also excluded. All attendants of patients were informed about written consent and written consent was taken from all of them. The data was collected using a predesigned proforma. The variables recorded were age, gender, type of classification of Michel and type of classification of Hiatt. A 128-slice CT scanner (Revolution Evo, GE) was used for abdominal CT angiography. The scan was taken from the dome of the diaphragm to the lower edge of the kidney (right sided). Coronal, Axial, Sagittal and 3D CT angiography images were acquired. The image thickness was 0.625 mm and images were obtained in the hepatic arterial phase.

An injector consisting of dual (two)-head power was used for contrast administration. 370 mg iodine/mL iopromide (Ultravist) was injected followed by 30 mL of sterile normal saline. Contrast medium and saline were rapidly injected at 4mL/s. An 18 (eighteen) gauge IV cannula was inserted into an antecubital vein. Imaging of arterial phase of liver was obtained between 11 and 20 seconds after the enhancement of the descending aorta had reached 150 HU. Multiplanar reformation was done in axial, coronal and sagittal planes. Volume rendering and maximum intensity projection were also used to perform 3D reconstruction. A consultant radiologist examined the images for the origin and the branching pattern of the coeliac axis and its major branches. Coeliac trunk and hepatic arterial system were evaluated individually. Anatomical variations were noted. The hepatic arteries were classified based on Michel's classification and Hiatt's classification of hepatic arteries. The hepatic arterial anatomy of Michel's Type I was thought to be the normal type. The Type II to Type X and unclassified patterns were thought to be anomalous hepatic arterial patterns, and these were classified as such and labeled as Type II-X. Hiatt's classification was also used to further categorize the hepatic artery variants.

Data was entered and analyzed using IBM SPSS Statistics version 25.0. Quantitative data (age) were presented as mean ± standard deviation, and qualitative data (gender, Michel's classification, Hiatt's classification, and hepatic arterial pattern) were presented as frequencies and percentages. Hepatic arterial anatomy was classified as normal if Michel's Type I was present and all other Michel's types and unclassified patterns were classified as anomalous hepatic arterial patterns.

Stratification was used to control for effect modifiers such as age and gender. Age was categorized into pre-defined groups and the relationship between anomalous hepatic arterial pattern and age group and sex was evaluated by Pearson chi-square test. A p-value of ≤0.05 was considered statistically significant. anxiety and the favourable superficial location of the lesion further supported timely intervention.

RESULTS

A total of 298 patients were included in the study. The mean age of the participants was 54.06 ± 11.59 years, with an age range of 15 to 65 years. Most patients were in the 46–60 years age group, and male participants were more frequent than female participants, as shown in Table I.

Table I. Baseline characteristics of study participants (n = 298)

Variable	Frequency / Value
Age (years)	
Mean ± SD	54.06 ± 11.59
Range	15–65
15–30 years	23 (7.7%)
31–45 years	18 (6.0%)
46–60 years	170 (57.0%)
61–65 years	87 (29.2%)
Gender	
Male	244 (81.9%)
Female	54 (18.1%)

Normal hepatic arterial anatomy was the most frequently observed pattern in the study population. According to Michel's classification, Type I anatomy was present in 220 patients (73.8%), while anomalous hepatic arterial patterns were observed in 78 patients (26.2%). Among the variants, Michel's Type III was the most common anomaly, followed by Type II and Type VI. A similar pattern was observed using Hiatt's classification, where Type I was the most frequent pattern and Type III was the most common variant, as shown in Table II.

Table II. Frequency distribution of hepatic artery variants according to Michel's and Hiatt's classifications (n = 298)

Classification	Type	Frequency	Percentage
Michel's classification	Type I	220	73.8%
	Type II	21	7.0%
	Type III	36	12.1%
	Type IV	3	1.0%
	Type V	3	1.0%
	Type VI	8	2.7%
	Type VII	0	0.0%
	Type VIII	1	0.3%
	Type IX	1	0.3%
	Type X	0	0.0%
	Unclassified	5	1.7%
Hiatt's classification	Type I	220	73.8%
	Type II	24	8.1%
	Type III	44	14.8%

	Type IV	4	1.3%
	Type V	1	0.3%
	Type VI	1	0.3%
	Unclassified	4	1.3%

Anomalous hepatic arterial pattern was observed in 66 males (27.0%) and 12 females (22.2%), with no statistically significant association between gender and arterial variation (p = 0.465). Similarly, the frequency of anomalous hepatic arterial pattern varied across age groups, being highest in the 31–45 years group; however, this association was also not statistically significant (p = 0.208), as shown in Table III.

Table III. Association of anomalous hepatic arterial pattern with age and gender (n = 298)

Variable	Category	Normal anatomy n (%)	Anomalous pattern n (%)	p-value
Gender	Male	178 (73.0%)	66 (27.0%)	0.465
	Female	42 (77.8%)	12 (22.2%)	
Age group	15–30 years	15 (65.2%)	8 (34.8%)	0.208
	31–45 years	10 (55.6%)	8 (44.4%)	
	46–60 years	129 (75.9%)	41 (24.1%)	
	61–65 years	66 (75.9%)	21 (24.1%)	

Test applied: Pearson chi-square test.

DISCUSSION

In the present study, normal hepatic arterial anatomy was seen in 220 patients (73.8%) and an anomalous hepatic arterial pattern was seen in 78 patients (26.2%). The slightly higher frequency of normal anatomy in the present study may be due to the difference in the study population because the local donor study was done in a transplant related population.[9] The present finding is also supported by regional comparison. A South Indian CT-based study reported normal hepatic arterial anatomy in 69% of cases and variant anatomy in 31%.[10] A Nepalese CT angiography study reported a lower frequency of variants, with normal anatomy in 86.7% and anomalous anatomy in 13.3% of patients.[11] A Sri Lankan CECT study reported variant hepatic arterial anatomy in 24.5%, which is very close to the present finding of 26.2%.[12] These differences are scientifically plausible because hepatic arterial anatomy may vary with ethnicity, sampling method, imaging protocol, and classification system. In the present study, the incidence of anomalous hepatic arterial pattern is in line with the literature from the region based on CT.
Michel's Type I was the most common pattern in the present study, seen in 73.8% of patients. This means that almost three-quarters of the study population had a conventional hepatic arterial anatomy. This finding validates the fact that the Type I of Michel is still the predominant hepatic arterial pattern, but a clinically significant minority of patients have vascular variation. A cadaveric study also revealed that the majority of specimens have the usual extrahepatic course of the hepatic artery, but rare variations may exist.[13] So, careful evaluation of the hepatic arterial anatomy is still necessary even when the conventional anatomy is anticipated.

The most common anomalous pattern in the current study was Michel's Type III. It was found in 36 patients (12.1%). This is a replaced right hepatic artery from the superior mesenteric artery. This relatively high prevalence of this variant in the current study may be due to the composition of the study population and the thin-section MDCT angiographic reconstruction. This variant is significant because the right hepatic artery can run near the head of the pancreas and the bile duct. It is important to recognize it prior to hepatobiliary and pancreatic procedures. Thus, Michel's Type III was the main contributor to anomalous hepatic arterial anatomy in this study.

Michel's Type II was the second most common anomaly in the present study. It was seen in 21 patients (7.0%). This pattern is a replaced left hepatic artery from the left gastric artery. The left hepatic artery variant is clinically important because it can traverse the gastrohepatic ligament and may be damaged during upper gastrointestinal, hepatic or transplant surgery. Thus, MDCT angiography should be carefully reported in Michel's Type II.

Other less common variants were also found in the current study. Type IV and Type V were seen in 1.0% of patients each. Type VI was seen in 2.7%. Type VIII and Type IX were observed in 0.3% each and Type VII and Type X were not observed. Rare variants are expected to have low frequencies because they are the result of less common embryological persistence or regression of ventral splanchnic arterial channels. Thus, the low prevalence of these variants in the current study is reasonable and reinforces the importance of careful image review.

Unclassified Michel's patterns were found in 5 patients (1.7%) in the present study. Hiatt's unclassified patterns were found in 4 patients (1.3%). This is important because not all hepatic arterial patterns can be fully described by older classification systems. The presence of unclassified cases in the present study is not unexpected as a recent report suggested that rare hepatic arterial variants may need new or expanded classification approaches when they do not fit into existing schemes.[16] Another liver donor study also questioned whether current classification systems are sufficient for all hepatic arterial variations.[17] It demonstrates that Michel's and Hiatt's systems are helpful, but not necessarily applicable to all arterial patterns seen in clinical practice.

Hiatt Type I was seen in 220 patients (73.8%) in the present study. Hiatt Type III was the most common variant (44 patients, 14.8%) followed by Type II (24 patients, 8.1%). This distribution is anticipated as the classification groups replaced and accessory arteries were grouped together. Therefore, Hiatt Type III can contain more cases than Michel's Type III alone. Hiatt's classification is simpler and is useful for clinical reporting and transplant assessment. It can also decrease anatomical detail, however, compared to Michel's classification. The current results suggest that both classifications should be used in combination for a comprehensive radiological description.

The mean age of the present study was 54.06 ± 11.59 years. Most patients were in the 46–60 years age group. No statistically significant association was found between age group and anomalous hepatic arterial pattern ($p = 0.208$). This is scientifically possible as the hepatic arterial variations are congenital anatomical patterns and are not normally acquired with age. The age distribution did influence the demographic profile of the sample, but did not significantly influence the presence of hepatic arterial variation, as a recent CT angiography study in patients with CHD also supports the concept that vascular variations are developmental anatomical findings rather than age-dependent changes.[18]

In the present study, male patients were more common than female patients. Anomalous hepatic arterial pattern was seen in 27.0% of males and 22.2% of females. This difference was not statistically significant ($p = 0.465$). The lack of a strong gender association is biologically plausible as the branching of the hepatic arteries occurs during embryogenesis and is not likely to be significantly different between males and females. The male predominance in the present study may be due to the hospital attendance pattern or indications for abdominal CT and not necessarily a true anatomical difference. Therefore, gender was not a significant factor in the hepatic arterial variation in this study.

In the present study, the replaced right and left hepatic arteries were the most clinically significant variants. These findings are important because these vessels can be damaged during pancreatic, biliary, gastric, hepatic or transplant surgery. The clinical significance of the present study is to enhance the preoperative recognition and systematic reporting of hepatic arterial anatomy, as an aberrant right hepatic artery is an important finding during pancreatic head surgery, although it does not always affect long-term outcomes.[19] An aberrant right hepatic artery may also influence the pattern of recurrence after pancreaticoduodenectomy, supporting the need for careful vascular mapping.[20] In addition, rare variants, such as an anteriorly passing replaced right hepatic artery, may create additional operative difficulty during pancreatic surgery.[23]

Limitations

This study had some limitations. It was a single-center study, so the findings may not represent the whole population. Non-probability consecutive sampling was used, which can introduce selection bias. The study was based on MDCT angiography findings and did not include routine surgical or catheter angiographic confirmation. Interobserver agreement was not assessed. The study focused on Michel's and Hiatt's classifications, so very distal segmental arterial branching was not evaluated in detail. Despite these limitations, the study provides useful local data on hepatic arterial variations using a practical and reproducible imaging method.

Future directions

Future studies should include multiple centers and larger sample sizes. This will improve the generalizability of data on local hepatic arterial variation. Future work should also compare MDCT findings with operative findings in patients undergoing liver transplantation, hepatobiliary surgery, or pancreatic surgery. Interobserver agreement between radiologists should be assessed to improve reporting reliability. Segmental hepatic arterial supply, including the segment IV arterial origin, should also be studied because it is important in liver donor evaluation. A structured MDCT reporting format for hepatic arterial anatomy may help surgeons and interventional radiologists plan procedures more safely.

CONCLUSION

Normal hepatic arterial anatomy was the most frequent pattern, while Michel Type III was the commonest variant. MDCT angiography was useful for identifying hepatic arterial variations.

PATIENTS' CONSENT:

Informed consent from the patients or their legal guardians was taken before the assessment, and their anonymity was ensured throughout the research.

COMPETING INTEREST:
The authors declared no conflict of interest.

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AUTHORS CONTRIBUTION
TR conceived the study, collected data, performed clinical assessment, and drafted the manuscript; TM supervised the study, guided methodology, reviewed clinical interpretation, and critically revised the manuscript; KR contributed to patient recruitment, data collection, clinical assessment, and manuscript review; MRN contributed to patient recruitment, data collection, clinical documentation, and manuscript review; MAK contributed to data collection, patient follow-up, clinical record review, and manuscript revision; RB provided academic supervision, reviewed the final manuscript, and approved the final version for submission.

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