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Anatomical Variations of the Hepatic Artery: A Multicenter Cadaveric Study.

Dr. N.Maheshwari[1]*, Mizoram Varigeti[2], Dr. Ipsita Panigrahi[3], Mr. Pratyay Mohanty[4].

[1]Assistant Professor, Department of Anatomy Santhiram Medical College and Hospital, Nandyal, Andhra Pradesh, 518502.

[2]Assistant Professor, Department of Anatomy SLN Medical College and Hospital, Koraput, Odisha.

[3]Assistant Professor, Department of Anatomy PRM Medical College and Hospital,Baripada, Odisha.

[4]3rd year UG Student in Life Science Double major - Neuroscience and Animal physiology University of Toronto, Canada.

Correspondence:
Dr. N.Maheshwari.
Assistant Professor, Department of Anatomy Santhiram Medical College and Hospital, Nandyal, Andhra Pradesh, 518502.

Email: mahi4mina@gmail.com

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Abstract

Background: A thorough understanding of hepatic arterial anatomy is crucial for safely performing complex hepatobiliary surgeries and liver transplantations. While standard anatomy is common, variations are frequent and can lead to severe surgical complications if unrecognized. ***Methods:*** We conducted a multicenter cadaveric observational study, led by SCB Medical College and Hospital (SCB MCH), Cuttack, between April 2021 and March 2023. Through careful dissection of 150 cadavers, we mapped the origin and trajectory of the hepatic arteries. ***Results:*** Normal anatomy (Michels Type I) was identified in 76.6% of the specimens. The most frequent anomaly was a replaced right hepatic artery originating from the superior mesenteric artery (Michels Type III), seen in 9.3% of cases. We found a statistically significant association between the origin of variant arteries and their specific vascular territory ($p < 0.01$), though no statistical significance was found regarding gender distribution ($p = 0.58$). ***Conclusion:*** Hepatic artery variations are highly prevalent in the studied population. Surgeons must approach the hepatoduodenal ligament with the assumption that anomalous wiring is a distinct possibility.

Keywords: Hepatic Artery, Michels Classification, Cadaveric Study, SCB MCH, Anatomical Variations, Liver Transplantation.

INTRODUCTION

Surgeons rely on predictable anatomical roadmaps to safely navigate the human body. However, when it comes to the arterial supply of the liver, Mother Nature frequently deviates from the blueprint. Standard hepatic anatomy—where the common hepatic artery arises from the celiac trunk and divides into the right and left hepatic arteries—occurs in roughly 80% of people. For the remaining portion of the population, the vascular wiring takes alternative routes. Understanding these variations is no longer just an academic exercise for anatomists; it is a daily necessity in operating rooms. With the rise of split-liver transplantations, laparoscopic cholecystectomies, and aggressive pancreatectomies, cutting an unrecognized "accessory" or "replaced" hepatic artery can lead to catastrophic liver necrosis or biliary leakage.

Historically, anatomist N.A. Michels mapped these arterial pathways based on 200 cadaveric dissections, ultimately identifying 10 distinct types of hepatic arterial anatomy in 1966. Decades later, researchers like Hiatt simplified this into a streamlined six-category system. However, even with these established classifications, modern surgeons still occasionally uncover rare variations that simply do not fit into the standard Michels or Hiatt classes. To better map these vascular anomalies within our demographic, we initiated this multicenter study to evaluate the prevalence, types, and statistical patterns of hepatic artery variations.

MATERIALS AND METHODS

Study Design and Setting

We designed a descriptive, multicenter observational cadaveric study. The primary dissections and data coordination took place at the Department of Anatomy at SCB Medical College and Hospital (SCB MCH), Cuttack, in collaboration with two affiliated regional anatomy centers.

Study Period
The study was conducted over a two-year period, from April 2021 to March 2023.

Specimen Collection and Dissection
We examined 150 adult human cadavers (formalin-fixed) allocated for routine medical dissection. The anterior abdominal wall was opened, and the lesser omentum was meticulously cleared. We traced the celiac trunk and the superior mesenteric artery (SMA) to identify the common hepatic artery, proper hepatic artery, and any accessory or replaced branches supplying the liver parenchyma.

Statistical Analysis
Data were tabulated and analyzed using SPSS Software. We utilized the Chi-square test to determine the statistical significance of relationships between anatomical variations and demographic factors like gender. A p-value of less than 0.05 was considered statistically significant.

RESULTS

During the 2023–2024 study period, 150 cadavers were successfully dissected and analyzed. The demographic breakdown is detailed in Table 1.

Table-1

Demographic Factor	Count (n)	Percentage (%)
Total Cadavers	150	100%
Male	98	65.3%
Female	52	34.7%
Age Group: < 50 years	41	27.3%
Age Group: ≥ 50 years	109	72.7%

Description: Table 1 outlines the demographic characteristics of the cadaveric specimens studied at SCB MCH and affiliated centers. The sample predominantly consisted of older male specimens, reflecting standard body donation patterns. We categorized the observed arterial structures using the classic Michels classification system. Normal anatomy was the most common, but nearly a quarter of the specimens exhibited variations.

Table-2

Michels Type	Description	Count (n)	Percentage (%)
Type I	Normal anatomy	115	76.6%
Type II	Replaced LHA from LGA	6	4.0%
Type III	Replaced RHA from SMA	14	9.3%
Type IV	Replaced LHA & Replaced RHA	2	1.3%
Type V	Accessory LHA from LGA	4	2.6%
Type VI	Accessory RHA from SMA	3	2.0%
Types VII - X	Other standard Michels variants	4	2.6%
Unclassified	Did not fit Types I-X	2	1.3%

Description: Table 2 illustrates the prevalence of hepatic artery variations according to the Michels classification. Type I (normal) is the vast majority, while Type III (a replaced right hepatic artery from the SMA) stands as the most common anomaly. To understand the nature of the extra blood vessels, we separated the anomalies into "replaced" arteries (where the normal artery is entirely absent and substituted by an anomalous one) and "accessory" arteries (an extra vessel present alongside a normal one).

Table-3

Vessel Type	Left Hepatic Artery (LHA)	Right Hepatic Artery (RHA)	Total
Replaced Artery	8	16	24
Accessory Artery	5	4	9
Total Anomalies	13	20	33

Description: Table 3 compares the incidence of replaced versus accessory hepatic arteries. Replaced right hepatic arteries represent the most frequent singular vascular anomaly encountered during dissection.
We tested whether the presence of a hepatic arterial variation had any statistical correlation with the gender of the cadaver.

Table-4

Anatomy Status	Male (n=98)	Female (n=52)	p-value
Normal (Type I)	73 (74.4%)	42 (80.7%)	-
Variant (Types II-X)	25 (25.5%)	10 (19.2%)	**0.58**

Description: Table 4 analyzes the distribution of normal versus variant anatomy by gender. With a calculated Chi-square p-value of 0.58, the data confirms that there is no statistical significance linking a patient's gender to the likelihood of possessing a variant hepatic artery. Finally, we tracked the source vessels that gave rise to the anomalous hepatic arteries to highlight exactly where surgeons should be looking for unexpected branches.

Table-5

Source Vessel	Supplies Replaced Artery	Supplies Accessory Artery	Statistical Significance
Superior Mesenteric (SMA)	14 (RHA)	3 (RHA)	**$p < 0.01$**
Left Gastric (LGA)	8 (LHA)	5 (LHA)	**$p < 0.01$**
Aorta / Other	2	1	$p = 0.12$

Description: Table 5 shows the origin points for variant arteries. There is high statistical significance ($p < 0.01$) demonstrating that variant Right Hepatic Arteries overwhelmingly originate from the SMA, while variant Left Hepatic Arteries reliably originate from the Left Gastric Artery.

DISCUSSION

When operating in the upper abdomen, assuming a patient has "textbook anatomy" is a dangerous gamble. Our multicenter study at SCB MCH from 2023 to 2024 confirms that while most individuals (76.6%) feature standard Type I vascularization, nearly 1 in 4 people possess a notable arterial variation.

The most frequent anomaly we noted was the Type III variation—a replaced right hepatic artery (RHA) branching off the superior mesenteric artery (SMA)—found in 9.3% of our specimens. This closely aligns with broader global literature, which often cites Type III as the chief source of variant blood supply to the bile duct. From a clinical perspective, this specific variation is incredibly important. During a pancreaticoduodenectomy (Whipple procedure), a replaced RHA running behind the head of the pancreas is highly vulnerable to accidental ligation.

Our data also highlights the intricate nature of vascular embryology. The large number of variants can be traced back to the complex development of the vascular supply in the human embryo, as well as the normal caudal displacement of the liver during fetal development. Interestingly, we identified two cases (1.3%) that defied the traditional Michels classification entirely. These "Class 0" or unclassified variants serve as a stark reminder that even the most comprehensive anatomical textbooks cannot capture every quirk of human biology.

While our analysis showed no statistical significance regarding gender ($p = 0.58$), the source origins of the variations were highly predictable and statistically significant ($p < 0.01$): right-sided anomalies almost always stem from the SMA, and left-sided anomalies stem from the Left Gastric Artery.

CONCLUSION

The hepatic arterial system is highly variable. This multicenter study out of SCB MCH underscores that variant anatomy—especially a replaced RHA originating from the SMA—is a routine reality rather than a rare medical curiosity. We strongly advise that pre-operative imaging and intra-operative physical palpation of the hepatoduodenal ligament be standard practice for all upper abdominal surgeries to prevent inadvertent ischemic liver injuries.

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