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Original Article

Variations in Hepatic Artery in Human Cadavers and its Importance in Surgery: A Prospective Study

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Abstract

Aim: The anatomical knowledge of the human body dates back to 500 years before Christ (BC) in Southern Italy with Alcmaeon of Crotona, who performed the first dissections, even in animals. In the 3rd century BC, the study of anatomy had advanced considerably in Alexandria and many discoveries made that there can be attributed to Herophilus and Erasistratus, the first to perform systematic human dissections.

Materials and Methods: A prospective observational study involving cadavers undergoing postmortem examination in the Department of Forensic Medicine in conjunction with the Department of General Surgery at Gajra Raja Medical College and J A Group of Hospital, on cadavers undergoing postmortem examination in the Department of Forensic Medicine between April 2017 and April 2018. It is a prospective observational study comprising 30 patients in each group.

Conclusion: Hence, in our study, maximum patients of Michels Type I were male (n=−16) followed by female (n=13), whereas patients with Michels Type III, one patient was male and another was female.

Key words: Cadaver, Comparative, Forensic medicine, Michels, Observational, Postmortem

INTRODUCTION

The anatomical knowledge of the human body dates back to 500 years before Christ (BC) in Southern Italy with Alcmaeon of Crotona, who performed the first dissections, even in animals. In the 3rd century BC, the study of anatomy had advanced considerably in Alexandria and many discoveries made that there can be attributed to Herophilus and Erasistratus, the first to perform systematic human dissections.

Galen was the first anatomist to examine in detail the arterial system from the celiac trunk, describing that the arteries, leading to the stomach, liver, and spleen, did not come from a common trunk in the aorta as the artery destined to the gut, but rather in two distinct branches. Andreas Vesalius gave anatomical descriptions superior to Galen's in the 16th century, commenting on a division into two branches of the celiac trunk: Right, corresponding to the hepatic artery, and left corresponding to the splenic artery that provides a gastric branch, the left gastric artery. However, Jacques Benigne Winslow and Albert Haller, considered the fathers of modern angiology, correctly defined the anatomy of the celiac trunk. Winslow completely described the trunk and its branches and Haller addressed the anatomical details of the anomalous hepatic artery.

Given the high incidence of variations in the hepatic arterial system and its influence on procedures involving the region, it is critical that it be thoroughly studied, detailed, and known by students and health professionals. This knowledge is relevant mainly for liver transplantation surgery. A significant number of complications can be avoided when the recognition of possible anatomical variations, both in organ donation and in liver implant, either from a living donor or from a cadaver.

The hepatic artery, a branch of the celiac trunk, may be divided into the common hepatic artery, from the celiac trunk to the origin of the gastroduodenal artery, and the

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hepatic artery proper, from the origin of the gastroduodenal artery to the bifurcation of the hepatic artery at or close to the porta hepatis, and the hepatic artery and hepatic portal vein terminate by dividing into right and left branches; these primary branches supply the right and left lobe of the liver livers, respectively.[6]

A small number of normal variants are important to demonstrate by angiography because they may influence surgical and interventional radiological procedures. A vessel that supplies a lobe in addition to its normal vessel is defined as an accessory artery. A replaced hepatic artery is a vessel that does not originate from an orthodox position and provides the sole supply to that lobe. Rarely, a replaced common hepatic artery arises from the superior mesenteric artery (SMA) and is identified at surgery by a relatively superficial portal vein (reflecting the absence of a common hepatic artery that would normally cross in front of the vein). More commonly, a replaced right hepatic artery (RHA) or an accessory RHA arises from the SMA.[7]

Table 1: Age at presentation

Age group	Frequency (%)
≤20	2 (5.9)
21–30	16 (47.1)
31–40	7 (20.6)
41–50	5 (14.7)
>50	4 (11.8)
Total	34 (100.0)

Table 2: Gender distribution

Gender	Frequency (%)
Female	15 (44.1)
Male	19 (55.9)
Total	34 (100.0)

Table 3: Findings

Findings	Frequency (%)
Michels Type I	29 (85.3)
Michels Type II	1 (2.9)
Michels Type III	2 (5.9)
Not accessible	2 (5.9)
Total	34 (100.0)

In this case, they run behind the portal vein and bile duct in the lesser omentum and can be identified at surgery by pulsation behind the portal vein. The accessory RHA may be injured during resections of the pancreatic head because the artery lies in close proximity to the portal vein. Occasionally, a replaced left hepatic artery (LHA) or an accessory branch arises from the left gastric artery: These vessels provide a source of collateral arterial circulation in cases of occlusion of the vessels in the porta hepatis but may also be injured during mobilization of the stomach as it lies in the upper portion of the lesser omentum. Rarely, accessory left or RHA may arise from the gastroduodenal artery or aorta. The presence of replaced arteries can be lifesaving in patients with bile duct cancer: Because they are further away from the bile duct, they tend to be spared from the cancer, making excision of the tumor feasible. Knowledge of these variations is also important in planning whole and split liver transplantation.[7]

Sometimes, the common hepatic artery arises from the SMA or aorta; the RHA may arise from the superior mesenteric (15%) and the LHA from the left gastric (20%).[8]

Due to the rapid increase in the number of liver transplants and laparoscopic cholecystectomy, the importance of hepatic artery anatomy has become apparent. In clinical practice, the in-depth knowledge of not only "standard" anatomy but also knowledge the variations in anatomical origin is essential to minimize morbidity encountered during hepatobiliary surgeries.

Aims and Objectives

The objectives of this study were as follows:

1. To study the branching pattern of hepatic arterial system in cadavers.
2. To determine the incidence of anatomical variations of hepatic artery.

MATERIALS AND METHODS

Prospective Observational Study

Study place

This study was conducted at the Department of Forensic Medicine in conjunction with the Department of General

Table 4: Comparing gender with findings

Gender	Findings				Total	*P* value
	Michels Type I	Michels Type II	Michels Type III	Not accessible		
F	13	1	1	0	15	0.41
M	16	0	1	2	19	
Total	29	1	2	2	34	

Surgery at Gajra Raja Medical College and J A Group of Hospital, Gwalior.

Source of data

A prospective observational study involving cadavers undergoing postmortem examination in the Department of Forensic Medicine in conjunction with the Department of General Surgery at Gajra Raja Medical College and J A Group of Hospital, Gwalior.

Inclusion Criteria

- All cadavers for whom informed consent will be obtained from their relative and the ethical committee.
- Cadavers aged above 16 years of age.

Exclusion Criteria

- Cadavers aged below 16 years.
- Mutilated and decomposed bodies.
- Those cadavers for whom consent were not obtained.
- Cadavers with operative procedure in subhepatic region or any subhepatic pathology-like tumors.

Sample size

Minimum of 30 cadavers, who fulfilled the above inclusion and exclusion criteria from Gajra Raja Medical College and J A Group of Hospital, Gwalior, were included in the study.

RESULTS

Majority of the patients in the present were belonged to the age group of 21–30 years (47.1%) followed by 31–40 years (20.6%).

Majority of the patients were male (55.9%) followed by female (44.1%).

The most common finding in the present study was Michels Type I in 85.3% followed by Michels Type III (5.9%).

Maximum patients of Michels Type I were male (n=−16) followed by female (n n=13), whereas patients with Michels Type III, one patient was male and another was female [Tables 1-4].[1-12]

DISCUSSION

1. The RHA is an end artery and contributes sole arterial supply to the right lobe of the liver. Misinterpretation of normal anatomy and anatomical variations of the RHA contributes to the major intraoperative mishaps and complications in hepatobiliary surgery. The frequency of inadvertent or iatrogenic hepatobiliary vascular injury rises with the event of an aberrant anatomy.
2. Knowledge of the anatomical variants in hepatic vascular structures is of great importance in general surgery, especially in hepatic and pancreatic surgery. This knowledge is also of great importance with regard to laparoscopic surgery, radiological procedures, and the treatment of penetrating injuries involving the perihepatic area. Computerized tomographic angiography helps to clearly delineate the vascular anatomy preoperatively, which would help the surgeon by anticipation of a vascular anomaly. Every attempt should be made to carefully dissect and preserve anomalous vessels unless their division or resection is dictated by the need to obtain oncological clearance.
3. An international classification describing the principal variations in the vascular anatomy of the liver was proposed by several authors, including Adachi in 1928, Michels in 1966, Hiatt in 1994, and Abdullah in 2006. Despite these studies, there are still some rare hepatic variations which are not found in these classifications.[29]
4. Michels described the hepatic arterial anatomy and its variations using the results of 200 cadaveric dissections and identified 10 types of hepatic arterial anatomy: Type I: Normal pattern; Type II: A replaced LHA from the left gastric artery; Type III: A replaced RHA from the SMA; Type IV: Replaced RHA and LHA; Type V: An accessory LHA; Type VI: An accessory RHA; Type VII: accessory RHA and LHA; Type VIII: A replaced RHA or LHA with other hepatic artery being an accessory one; Type IX: The hepatic trunk as a branch of the SMA; and Type X: The CHA from the left gastric artery.[2]

The classification of Michels was modified by Hiatt who distinguishes six categories: The normal anatomy – Hiatt Type I, the LHA arising from the left gastric artery – Hiatt Type II, the RHA arising from the SMA – Hiatt Type III, every combination of a double replaced pattern – Hiatt Type IV, the CHA originating as a branch of the SMA – Hiatt Type V; and the abnormality consisting of an isolated aortic origin of the CHA, which Hiatt introduced as Type VI instead of including the rare variant with a CHA arising from the left gastric artery.

5. We have used the Michels classification because from the surgical point of view; we believe that is more complete since it establishes the differences between "an accessory" and "a replaced" artery concepts not explained in more recent classifications.

Majority of the patients in the present were belonged to the age group of 21–30 years (47.1%) followed by 31–40 years (20.6%).

In the present study, majority of the patients were male (55.9%) followed by female (44.1%). Dandekar *et al.*

reported that of 60 adult embalmed cadavers, 56 were male and 4 were female.

Lopez-Andujar *et al.* investigated 1081 donor livers and compared the findings with Michel's classification. They found two new types which are not included in Michel's classification. Hiatt *et al.* and Abdullah *et al.* modified Michel's classification and classified the hepatic arteries into six types. In the present study, the most common finding in the present study was Michels Type I in 85.3% followed by Michels Type III (5.9%). Type III (replaced RHA) is the most common variant (3.7%) according to Michels. In the present study, Type I was more common that it may be due to the small sample size in our study. Dandekar *et al.* in a similar study involving 60 adult embalmed cadavers reported that the "classic" hepatic arterial anatomy is present in approximately 55–75% of the cases. According to literature, normal origin of RHA from PHA was seen in 80.4% of the cases. Németh, in 2016, studied 50 corrosion casts and reported that 41 casts (82%) could be classified according to Michels. 21 cases (42%) showed normal arterial pattern (Michels I), while 29 cases (58%) presented different types of extrahepatic arterial variations. However, 9 cases (18%) displayed variations not described in the Michels' classification.

The hepatic artery variations can usually be explained in terms of developmental basis. The liver is supplied during the fetal life by three arteries – RHA from SMA, LHA from the left gastric artery, and common hepatic artery from the celiac trunk. With further development, the blood supply assumes the adult pattern, with atrophy of both the right and left hepatic arteries, and the CHA gives off the right and left hepatic arteries supplying the whole liver. Anatomical variations correspond to the result of partial or complete persistence of the fetal pattern.

Our series shares the general findings of the low percentage of Michel's Types II, III, and IV; however, discrepancies of other patterns are obvious. These may be explained with the low number of cases in our series, population differences, and misinterpretation of radiological findings in other investigations due to respiratory motion artifacts, wrong catheter positioning, narrow diameter, or slow flow in the small aberrant vessel. Radtke *et al.* proposed the most complex classification for the right-sided segmental variations and set up seven different types of the peripheral branching patterns. We found seven arterial structures described neither by Radtke *et al.* nor by other authors. These variations include RAHA trifurcation (1/50), RHA trifurcation (2/50), absence of RAHA (2/50), absence of RPHA (7/50), non-existent RAHA and RPHA (3/50), RHA giving A2 (1/50), and proximally originating RPHA coursing behind the portal vein (1/50).

Class 2, characterized by the LHA originating from the left gastric artery, was found only in 2.9% of subjects in our study and literature shows a low prevalence of it. Bertevello and Chaib, who conducted the study in 60 livers from cadavers, showed only 2 cases (3.3%) of this variation. Hiatt *et al.* obtained 9.7%.

Regarding the RHA originating from the SMA (Class 3), we found 2 cases (5.9%) and it was the most significant alteration recorded. In literature, the values are between 8% and 18%. We believe that this type of variation presents with more relevance both for its greater prevalence and the potential to affect surgical procedures. As the vessel passes between the inferior vena cava and the portal vein at the level of the hepatobiliary triangle, one should be very careful in surgeries such as cholecystectomy and also pancreatectomy.

When we compared the findings with age groups, we found that Michels Type I was most common among the patients of 21–30 years of age (*n*=14) followed by 31–40 years (*n*=6). Among the patients with Michels Type III, one patient was present in 21–30 and 31–40 years of age group. The comparison was insignificant (*P*=0.104). Maximum patients of Michels Type I were male (*n*=–16) followed by female (*n*=13), whereas patients with Michels Type III, one patient was male and another was female. Comparing the findings with chief complaint made by the study cohort, we found that maximum cadavers of Michels Type I had burns (*n*=12) followed by hanging (*n*=9) and poison in 5. However, we did not find any study comparing the Michels Type with the demographic parameters of the subjects.

Anatomical knowledge of variants of hepatic artery is required to reduce the iatrogenic complications in hepatobiliary surgeries, surgical management of liver trauma, aneurysm of hepatic artery, hepatic arterial infusion chemotherapy, liver transplant surgery, pancreaticoduodenectomy, radical gastrectomy, and such other surgeries of this complex anatomical region. These variants are relevant in cholecystectomy because they affect the laparoscopic appearance of porta hepatis.

In liver transplants, appropriate evaluation of hepatic arteries is essential for reducing operative and post-operative morbidity and mortality in both donors and recipients. The presence of anatomical variation of hepatic artery in the donor requires an adaptation of arterial reconstruction technique to obtain an optimum perfusion of territories of the graft and avoid complications like thrombosis of the hepatic artery. Replaced RHA is a beneficial variant in the right liver living donors. The common post-operative complication in liver transplantation is hepatic artery thrombosis due to shorter and thinner hepatic artery graft. However, replaced RHA in the right lobe liver "donor" provides a longer and larger graft, thus reducing chances of hepatic artery thrombosis in them. Replaced RHA in liver transplant "recipient" increases risk of hepatic artery complications after transplantation due to small caliber of common hepatic artery.

The present study has few limitations. First, cross-sectional nature of the present study was the main limitation which restricts the use of the present study findings to large population. Second is the small sample size; a large randomized clinical trial is required to strengthen the present study findings.

CONCLUSION

In the present study, Michels Type I was the most common which go hand in hand with the previous landmark studies.

In conclusion, the hepatic arterial anatomy represents one of many "lessons for the general surgeon." These arterial patterns are of importance in the planning and performance of all surgical and radiological procedures in the upper abdomen.

Variant arterial anatomy recognized during cadaveric dissection offers great learning potential and provides alternative perspective to view common morphology with its structural and functional importance. These impart the concept of patient individuality and subsequent individualization of medical and surgical therapies.

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