ORIGINAL ARTICLE

Anatomical Variations of Hepatic Arterial Anatomy on Abdominal Computed Tomography in over 300 Scans

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Abstract

Objective: Identifying anatomical variations in the hepatic artery is crucial before performing surgical or radiological interventions to avoid damaging abnormal, replaced, or uncommon arterial supplies. Our study measured the occurrence of hepatic arterial anatomical variations in a local population using computed tomography (CT).

Materials and Methods: We analyzed all abdominal CT studies with intravenous contrast conducted at King Abdulaziz University Hospital over one fiscal year. The study included 351 studies. Michel's and Hiatt's classification systems were adopted to describe the variations.

Results: Our study of 351 abdominal CT scans discovered that the accessory left hepatic artery (Type V) was the most prevalent abnormal variation based on Michel's classification, occurring in 13.1% of cases. Hiatt's classification identified the replaced or accessory left hepatic artery (Type II) as the most common abnormality in 19.1% of cases. Other variations were observed.

Conclusion: Our study highlights the significance of hepatic artery variations in liver surgery and interventional radiology, such as the presence of accessory left hepatic arteries and replaced hepatic arteries. Understanding these variations is crucial for optimizing patient care and improving outcomes in various clinical scenarios. Ongoing research is crucial for advancing this field.

Keywords

Hepatic artery, Anatomical variation, Computed tomography, Accessory left hepatic artery, Surgical practice

INTRODUCTION

Blood is supplied to the liver from 75% to 85% from the portal vein and 20% to 25% from the hepatic artery[1]. Arterial buffering plays a crucial role in regulating the dual hepatic blood supply, a unique phenomenon aimed at maintaining a consistent flow of oxygenated blood to the liver. The hepatic artery undergoes dilation when there is a decrease in portal blood flow; conversely, when there is an increase in portal blood flow, the hepatic artery constricts[2]. On the other hand, the biliary tree obtains its blood supply solely from the hepatic arterial system[1]. Therefore, it is directly influenced by the compromise of the hepatic artery. Therefore, to prevent unforeseen surgical complications such as hemorrhage or ischemia, it is of utmost importance to understand the anatomical variations of the hepatic artery.

Michel's classification for variations in the hepatic artery was first published in 1966, using data from 200 autopsy dissections[3]. They categorize these variants into ten different variants, as shown in Table 1. In 1994, Hiatt et al. reviewed the variation of hepatic arterial anatomy in a sample of 1,000 patients who had undergone liver harvesting for orthotopic liver transplantation, as documented in operative note records[4]. They categorized accessory or replaced vessels into a single category and published a modified classification of the six variants.

Although the classification systems rely on autopsy and operative records, computed tomography (CT) can be employed to radiologically illustrate hepatic artery variations in accordance with these classifications. Although CT may not be a definitive method for illustrating hepatic artery variations, it is the preferred imaging modality because of its non-invasive nature and minimal risk of complications[5]. In contrast to digital subtraction, angiography (DSA) is the gold standard in this field. DSA is an invasive procedure associated with a higher incidence of complications. Two studies were conducted in Turkey using patients' CT images to illustrate the hepatic artery variability. Both studies indicated that CT scans are equally effective[6,7].

Anatomical variations in the hepatic artery are crucial before performing upper abdominal surgeries, including liver transplantation, pancreatoduodenectomy, or biliary reconstruction[8]. Endovascular interventions, such as chemoembolization[6], are also important to prevent atypical hepatic arterial supply damage. Failure to do so may lead to unexpected intraoperative complications such as biliary ischemia and potential hepatic impairment[9]. Therefore, this study aimed to review the arterial phase of CT scans at King Abdulaziz University Hospital (KAUH) to document anatomical variations of the hepatic artery and compare them with percentages published in radiological and anatomical studies.

MATERIALS AND METHODS

Study Design

This retrospective study was conducted at KAUH, a tertiary care hospital located in Jeddah, Saudi Arabia. All abdominal CT studies with intravenous contrast enhancement during the arterial phase were collected over the course of an entire fiscal year. Patients who underwent multiple CT scans during the specified review period were excluded. Studies with non-arterial phases were also excluded. A comprehensive analysis incorporated 351 studies. Ethical approval was obtained from the Unit of Biomedical Ethics at King Abdulaziz University (KAU). The Institutional Review Board (IRB) has granted a waiver for the informed consent requirement because this study was conducted retrospectively, and patient data were anonymized to ensure privacy protection.

Image Analysis

The data were obtained by thoroughly examining the reports from the abdominal CT studies that were included. The focus of these reports was specifically on arterial anatomy. Additionally, a liver surgeon conducted a thorough review of the data to validate its accuracy and supplement any incomplete information from the CT reports by examining the images. Upon completing the data collection process, an independent radiologist conducted a comprehensive review of the images to determine the precision and dependability of the findings. Michel's[3] and Hiatt's[4] classification systems were used to delineate the different variations, as presented in Table 1 and Table 2. Both classification systems have established that a common hepatic artery branching from the celiac trunk is considered a normal anatomical feature. Michel's classification system delineated ten variants, encompassing the presence of the common hepatic artery from the left gastric artery. However, it did not encompass the common hepatic artery from the aorta (Figure 1). Hiatt's classification system failed to provide a description of the common

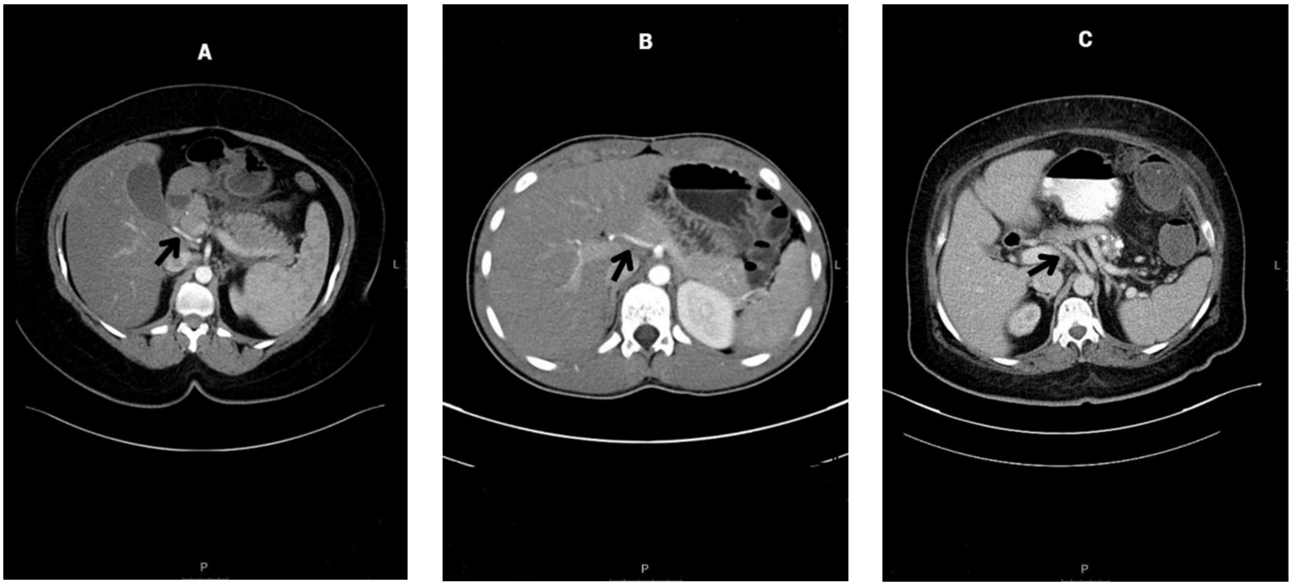

Figure 1. **Replaced right hepatic artery from the superior mesenteric artery (A), replaced left hepatic artery from a left gastric artery (B), and common hepatic artery from the aorta (C). Arrow.**

Table 1. **Michel's Classification System.**

Classification	Description	Incidence in our Population (%)
I	Normal anatomy (common hepatic artery branching from the celiac)	221 (62.9)
II	Replaced the left hepatic artery from the left gastric artery	21 (5.9)
III	Replaced the right hepatic artery from the superior mesenteric artery	32 (9.1)
IV	Replaced the right and left hepatic arteries	1 (0.2)
V	Accessory left hepatic artery	46 (13.1)
VI	Accessory right hepatic artery	3 (0.8)
VII	Accessory right and left hepatic arteries	0 (0)
VIII	Replaced right hepatic artery and accessory left hepatic artery OR Replaced the left hepatic artery and accessory right hepatic artery	14 (3.9)
IX	Common hepatic artery from the superior mesenteric artery	6 (1.7)
X	Common hepatic artery from the left gastric artery	0 (0)

Table 2. **Hiett's Classification System.**

Classification	Description	Incidence in our Population (%)
I	Normal anatomy (common hepatic artery branching from the celiac)	221 (62.9)
II	Replaced or accessory left hepatic artery	67 (19.1)
III	Replaced or accessory right hepatic artery	35 (9.9)
IV	Replaced or accessory right hepatic artery + Replaced or accessory left hepatic artery	14 (3.9)
V	Common hepatic artery from the superior mesenteric artery	6 (1.7)
VI	Common hepatic artery from the aorta	7 (2)

hepatic artery from the left gastric artery. During our research, we encountered both variants, necessitating the use of both classification systems.

Data Collection

Data collection was conducted using a carefully designed data sheet aligned with the study's specific objectives. Data was collected from the available reports. Missing information was obtained by reviewing the CT scans. The extracted data was securely stored in an Excel spreadsheet on a protected computer system to maintain patient confidentiality.

RESULTS

We conducted a review of 351 abdominal CT scans performed using arterial contrast. The distribution of patients' sex was equal, with 47.86% being male and 52.14% being female. The predominant anatomical variation observed in both Michel's and Hiatt's classification systems was the presence of normal anatomy, specifically the common hepatic artery branching from the celiac artery (Type I), which accounted for 62.9% of cases. The predominant anomaly in Michel's classification system is the presence of an accessory left hepatic artery (Type V) (13.1%), as shown in Table 1. Similarly, Hiatt's classification system identifies the occurrence of a replaced or accessory left hepatic artery (Type II) (19.1%), as indicated in Table 2. Other less frequently encountered variations are displayed in Tables 1 and 2. In Michel's classification system, the variant of the accessory right and left hepatic arteries (type VII). The variant of the common hepatic artery from the left gastric artery (type X) was not observed in any of the patients included in the study (see Table 1).

DISCUSSION

The common hepatic artery is a derivative of the celiac artery. The right gastric artery is identified as the initial branch, followed by the gastroduodenal artery. Then, the artery transforms into the proper hepatic artery, which ultimately ends at a point of division to generate the right and left hepatic arteries. This common variant has been observed in most populations in the literature, with prevalence rates ranging from approximately 55% to 90%[3,4,6,7,10-13]. With the rising prevalence of liver transplantations, resection of liver malignancies, and radiological arterial-directed therapy, it is crucial for physicians involved in treatment to have a comprehensive understanding of these variations.

The classification of hepatic artery variations was originally established by Michel in 1966[3], using 200 autopsy dissections as the basis for his classification. He provided a description of ten different variations, as shown in Table 1[3]. Another classification system was formulated by Hiatt et al. in 1994[3]. The authors conducted a comprehensive analysis of the hepatic artery anatomy in a sample of 1000 patients who underwent liver harvesting for orthotopic liver transplantation. The accessory and replaced arteries were categorized together, describing six variants (Table 2)[4].

The most prevalent atypical variation in the hepatic artery, as classified by Michel, is the accessory left hepatic artery (type V) (13.1%). This was followed by the replacement of the right hepatic artery from the superior mesenteric artery (type III) (9.1%) and the replacement of the left hepatic artery from the left gastric artery (type II) (5.9%) (Table 1) (Figure 1). According to Hiatt's classification, the most prevalent abnormal variation observed was the replaced or accessory left hepatic artery (type II) at a frequency of 19.1%. This was followed by the replaced or accessory right hepatic artery (type III) at a frequency of 9.9% (Table 2). According to Chaudhari et al.[14], in a systematic review, the most prevalent abnormal variation observed was the replacement of the right hepatic artery from the superior mesenteric artery (type III), with a prevalence of 7.2%. This was followed by the accessory left hepatic artery (type V), which was replaced by the left hepatic artery from the left gastric artery (type II), with prevalences of 6.2% and 1.7%, respectively. Therefore, the three most prevalent abnormal variations exhibited consistent patterns across the studies.

Variations in hepatic arterial anatomy can have significant implications for planned intervention in patients undergoing liver tumor resection or liver transplant surgery. Therefore, conducting an accurate preoperative assessment of the hepatic vascular anatomy is crucial. The significance of this assessment depends on the specific type of variation and the procedure that will be executed.

In the context of living donors, variations in liver transplant procedures can impact either the donor or recipient. A study by Soliman et al. revealed that liver transplant patients with hepatic artery variations are more likely to experience arterial complications[15]. Therefore, gaining a comprehensive understanding of hepatic arterial variations could reduce the occurrence of postoperative complications in liver transplant procedures. In relation to the recipient, it is crucial to consider the blood supply of Segment IV in donor procedures. This blood supply can originate solely from the right hepatic artery or from a combination of the right hepatic artery, middle hepatic artery, and left hepatic artery. Therefore, it is essential to know hepatic artery variations to preserve the arterial supply to segment IV for the donor[16]. For instance, a variation that could impact the recipient, particularly segment IV, is the presence of an accessory right hepatic artery (known as Michel's type VI and Hiatt's III). Anastomoses with the gastroduodenal artery are required to maintain a blood supply. However, this approach may lead to postoperative complications such as anastomotic rupture, bleeding, or thrombosis, which could adversely affect the recipient[17]. In contrast, the substitution of the right hepatic artery with the superior mesenteric artery, specifically classified as Michel's type III and Hiatt's type III, would have implications for both the donor and recipient because of its impact on the process of harvesting and revascularization (see Figure 1).

The ability to resect a liver tumor is influenced by the arterial anatomy and its proximity to the tumor[9]. Hepatic artery anomalies have the potential to impact the viability and surgical approach of tumor resection. A comprehensive evaluation of arterial circulation before surgery is of utmost importance in such cases because it helps prevent ischemia in the future liver remnant and minimizes the risk of biliary ischemia. The impact is also contingent on the tumor's location and the specific type of variation. Right lobe resection is influenced by the presence of a replaced right hepatic artery from the superior mesenteric artery and an accessory right hepatic artery (classified as Michel's type III and VI and Hiatt's type III, respectively). In contrast, resection of the left lobe is influenced by the presence of a replaced left hepatic artery from the left gastric artery (as shown in Figure 1), as well as the presence of accessory left hepatic arteries, specifically Michel's type II and V and Hiatt's type II. The presence of a common hepatic artery from the superior mesenteric artery (Michel's type IX and Hiatt's type V) or a replaced hepatic artery from the left gastric artery (Michel's type II and Hiatt's type II) can have an impact on the resection of the right or left lobe[18].

Of notable importance is the anatomical variability observed in instances of perihilar cholangiocarcinoma, commonly referred to as Klatskin tumors. Due to their proximity to the major hepatic artery and portal venous branches in the hilum and the desmoplastic reaction they elicit, these tumors result in tethering and/or entanglement of the blood vessels. Resection and reconstruction of the hepatic artery significantly enhance the likelihood of achieving R0 resection, as supported by previous studies[19]. Therefore, consideration of anatomical variations in the hepatic arteries and/or portal vein is of utmost importance during pre-operative and intraoperative resection planning to achieve R0 resection. It has been observed in our experience that the successful attainment of an R0 resection is frequently contingent upon the existence of a replaced right hepatic artery from the superior mesenteric artery (specifically, Michel's type III and Hiatt's type III) in instances of predominantly left-sided perihilar cholangiocarcinoma, or vice versa.

In patients with non-resectable tumors, intra-arterial chemoembolization presents as a viable treatment alternative. Chemotherapeutic agents are administered through targeted hepatic artery infusion, to deliver the maximum dosage directly to the tumor site. Careful delineation of the hepatic artery is crucial in such cases. Planning and positioning a pump according to the standard anatomical structure in a patient with arterial variations, such as a replaced or accessory artery, can lead to treatment failure or suboptimal outcomes.

CONCLUSION

In conclusion, our study highlights the significance of comprehending hepatic artery variations, as classified by Michel and Hiatt, within the realm of liver surgery and interventional radiology. The most common variations of the hepatic artery, identified through an analysis of abdominal CT scans, include the accessory left hepatic artery, the replaced right hepatic artery from the superior mesenteric artery, and the replaced left hepatic artery from the left gastric artery. These variants have been identified as common anomalies in both classification systems. Furthermore, our study illuminates the extensive implications of hepatic artery variations in various medical scenarios. These variations significantly affect liver transplantation, liver tumor resection, and intra-arterial chemoembolization procedures. They affect surgical techniques, postoperative complications, and treatment results.

Our study emphasizes the crucial significance of understanding hepatic artery variations to enhance patient care and achieve successful outcomes in various clinical contexts, including transplantation, oncological surgery, and interventional radiology. Ongoing research in this field is essential for continuously refining our knowledge and advancing clinical practice.

Conflicts of Interest

The authors have no conflicts of interest to declare. All co-authors have seen and agreed with the manuscript's contents, and there is no financial interest to report. We certify that the submission is an original work and is not under review at any other publication.

Disclosure

The authors did not receive any form of commercial support, either in the form of compensation or financial assistance, for this case report. The authors have no financial interest in any of the products, devices, or drugs mentioned in this article.

Ethical Approval

The study was approved by the Ethics Committee of the KAUH in Jeddah, Kingdom of Saudi Arabia, also known as the Institutional Review Board of Hospitals.

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