



## Anatomical Variations of the Hepatic Artery in a South African Population: A Cross-Sectional Cadaveric Study

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### ABSTRACT

Variations in hepatic artery anatomy are common, impacting surgical and interventional procedures. This study aimed to document hepatic artery variations in South African cadavers using Michels's classification. In this retrospective cross-sectional study, thirty cadavers with intact hepatic arteries were included from Sefako Makgatho Health Sciences University, South Africa were dissected, focusing on the hepatic artery and its branches. Arterial configurations were classified according to Michels's system (Types 1-10). Sex and race data were also collected. All the data were entered into SPSS version 21. Out of total 30 cadavers, 21 (70%) were males and 9 (30%) were female cadavers. Africans were 21 (70%), and Caucasians were 9 (30%). Type 1 (53.3%) was the most prevalent variation, followed by Types 5 and 9 (10% each). The right hepatic artery (RHA) arose from the proper hepatic artery in 80%. The left hepatic artery (LHA) originated from the proper HA in 76.7% of cases. Analysis by sex revealed Type 1 being the most common in both genders, with additional variations (Types 5 and 9) observed only in males. By race, Type 1 was predominant in both Africans and Caucasians, but was slightly more prevalent in Caucasians. Hepatic artery variations were present in nearly half of the studied cadavers. Awareness of these variations, particularly Types 5, 9, and those affecting RHA and LHA origins, is crucial for surgeons to minimize complications and optimize surgical outcomes.

### 1. INTRODUCTION

Vascular anomalies, such as artery and vein deviations, are frequently encountered accidentally during surgical and diagnostic imaging operations. These variations are prevalent in the abdominal region. (1) Variations in the anatomy of hepatic arteries are commonly encountered, ranging between 13% and 48%. (2) Knowledge about these anatomical differences in hepatic arteries is crucial for the preparation of

hepatobiliary surgical procedures, liver transplantation and donor operations, transarterial treatments, and various other endovascular procedures. (3)

Comprehending the different patterns of the hepatic artery's anatomy is crucial for all surgical interventions related to the liver and pancreas. This knowledge impacts the planning and execution of these treatments since the complex

circulatory networks around these organs are involved. This information is vital in laparoscopic surgeries and interventional radiological procedures, such as bleeding embolization, transcatheter arterial chemoembolization, and transarterial radioembolization. (4) Aberrant anatomy and variations increase the frequency of iatrogenic hepatic vascular injuries. (5) If such variations exist and are not identified through appropriate preoperative evaluations, surgical techniques may need to be altered to mitigate the potential for unintended hemorrhaging or biliary complications. (1, 6)

Studies conducted in various parts of the world and on multiple ethnicities revealed variations in HA configuration. A study in Egypt reported 74.3% Michels Type 1 cases, followed by Michel Type 3 with 12.5% incidence. (7) Another study conducted in Kerala, India, on cadavers reported 8.5% of cases other than the typical Type 1. (8) CT scans were used to evaluate the HA configuration in 205 patients in the West Indies. There were 112 (54.6%) individuals with typical Type 1 anatomy. Michels's Type 2 and 3 patterns were the most prevalent anatomic varieties found in 14.6 % and 18.1 % of cases, respectively. (9).

A retrospective study was conducted at Groote Schuur Hospital in the Western Cape Province, South Africa. The study involved 300 MDCT scans and attempted to assess the normal and variant anatomy of the hepatic artery system using Uflacker's and modified Michel's criteria. The results indicated that 55% (n=165) had a hepatic artery system that was within the normal range. The most common variation discovered was the auxiliary left hepatic artery, which was present in 12.7% (n=38) of patients. 30.7% of the hepatic artery's anatomy was categorised, while the remaining 14.3% was unclassified. Significantly, the observed variations consisted of a twin hepatic artery in 2.7% of cases and a trifurcation of the common hepatic artery in 5.3% of cases. (10)

In South Africa, laparoscopic cholecystectomy is among the most commonly performed operations in the state and private sector at a rate of 13.81 per 100,000 population. (11) The incidence of complications is reported at 1–2%. Most complications occur due to anomalous dissection or anatomical variations. Population-specific variations in vascular anatomy have previously been demonstrated in South African populations.

(12)

There are limited population-specific studies to determine the incidence of HA variation, particularly in African groups. (10, 13) The variation in different populations and its importance for multiple surgical procedures prompted us to determine the HA configuration in the South African population. The study aimed to record the variant patterns of the hepatic artery in a sample of South African cadavers and classify these patterns according to Michels's classification. (14)

## 2. MATERIALS AND METHODS

**Study Design:** This was a retrospective cross-sectional study conducted in a sample of South African cadavers.

**Study Setting:** The study included 30 cadavers from Sefako Makgatho Health Sciences University, South Africa. The cadavers were sourced from the Gauteng area.

**Study Samples:** The researcher undertook a fine dissection where the undergraduates had done prior dissection to identify the vessels of interest. Cadavers with intact hepatic arteries were included, and cadavers with previous upper GI and hepatobiliary surgery resulting in disruption of the hepatic arterial system were excluded.

**Data Collection:** The lead researcher conducted the dissections and recorded the findings in the data collection sheet. The sex and race of each cadaver were documented. The dissection was performed using a standard, well-described dissection technique. (15) The dissected CHA left gastric and the SMA were photographed. The configuration of the hepatic artery was tabulated according to Michels's classification system of Type 1 to Type 10. (14) The origins of the following arteries were recorded: CHA, CT, SMA, gastroduodenal artery, RHA, left hepatic artery and cystic artery. Variations of the CHA and singular hepatic arteries about their origins and anatomic sequences were also included in the broad category of hepatic arterial variation (Fiorello & Corsetti, 2015).

**Data Analysis:** All the data were entered into SPSS version 21. Descriptive tests were applied to find out the frequencies and percentages. We examined individual hepatic arterial variations as the subsequent step in the present study's analysis of hepatic arterial variation.

**Ethical Considerations:** Ethical clearance was obtained from SMUREC before the researcher resumed data collection. The use of the cadaveric material is in accordance with the Human Tissue Act (65 of 1983). Ethical Committee number (SMUREC/M/185/2022: PG).

### 3. RESULTS

Out of total 30 cadavers, 21 (70%) were males and 9 (30%) were female cadavers. Africans were 21 (70%), and Caucasians were 9 (30%).

Table 1: Demographic Data

| Characteristics | Frequency | Percentage |
|-----------------|-----------|------------|
| <b>Gender</b>   |           |            |
| Male            | 21        | 70%        |
| Female          | 9         | 30%        |
| <b>Race</b>     |           |            |
| Africans        | 21        | 70%        |
| Caucasian       | 9         | 30%        |

According to Michels's classification of hepatic arterial anatomy, Type 1 was the most prevalent found in 53.3% (n=16) of the cadavers followed by Type 5 and Type 9 observed in 3 (10%) cadavers. Type 3 was found in 2 subjects (6.7%). Type 2, Type 4, Type 6, and Type 7 were found in 1 cadaver.

We did not find any case of Type 8. However, 2 cases of Type 10 (Figure 4-6), or unclassified, were detected (**Table 2**).

Table 2: Variations of the hepatic artery as per Michels's classification

| Type as per Michels's classification | Frequency | Percentage |
|--------------------------------------|-----------|------------|
| Type 1                               | 16        | 53.3%      |
| Type 2                               | 1         | 3.3%       |
| Type 3                               | 2         | 6.7%       |
| Type 4                               | 1         | 3.3%       |
| Type 5                               | 3         | 10.0%      |
| Type 6                               | 1         | 3.3%       |
| Type 7                               | 1         | 3.3%       |
| Type 8                               | 0         | 0.0%       |
| Type 9                               | 3         | 10.0%      |
| Type 10                              | 2         | 6.7%       |

Type 1 is the most common in both genders. Type 5 and Type 9 were found only in males. Type 3 was present in females. Types found in only 1 cadaver were Type 4, Type 6 and Type 7, reported in females (**Figure 1**).

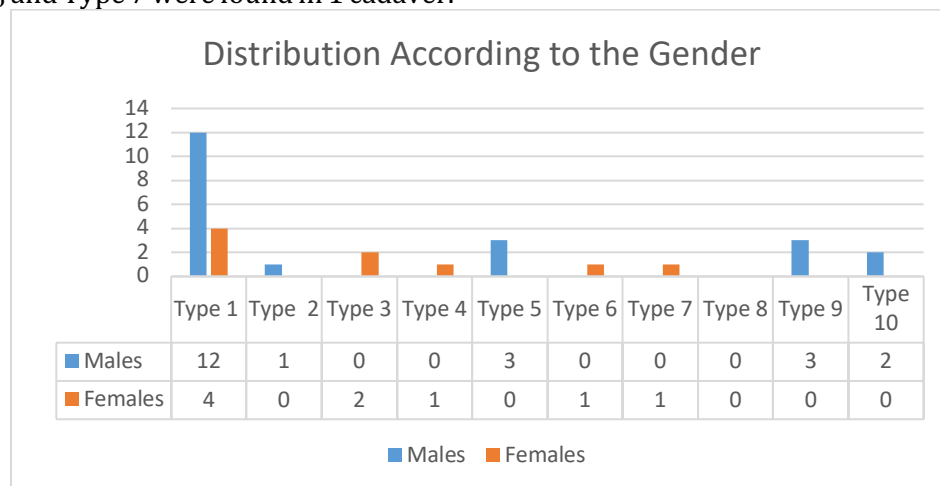


Figure 1: Distribution of hepatic artery as per Michels's classification according to the gender

Type 1 is the predominant variation among Africans and Caucasians. It is more prevalent in Caucasians. Our analysis found that 66.7% (n = 6) of Caucasians had this variation, and 47.6% (n = 10) Africans reported Type 1. All three cases of Type 5 were reported in Africans (**Table 3**).

Table 3: Variations of the hepatic artery as per Michels's classification according to race

| Type as per Michels's classification | African    | Caucasians |
|--------------------------------------|------------|------------|
| Type 1                               | 10 (47.6%) | 6 (66.7%)  |
| Type 2                               | 1 (4.8 %)  | 0 (0.0%)   |
| Type 3                               | 1 (4.8 %)  | 1 (11.1%)  |
| Type 4                               | 1 (4.8 %)  | 0 (0.0%)   |
| Type 5                               | 3 (14.3)   | 0 (0.0%)   |

|         |           |           |
|---------|-----------|-----------|
| Type 6  | 1 (4.8 %) | 0 (0.0%)  |
| Type 7  | 0 (0.0%)  | 1 (11.1%) |
| Type 8  | 0 (0.0%)  | 0 (0.0%)  |
| Type 9  | 2 (9.5%)  | 1 (11.1%) |
| Type 10 | 2 (9.5%)  | 0 (0.0%)  |

In 24 (80%) of the cases, the RHA originated from the proper HA. We found the RHA arising from the SMA corresponding to 10% (n = 3) of the cadavers. The CHA was the source of RHA in the case of 1 (3.3). We found 2 (6.7%) cases where RHA originated from the SMA and proper HA. Regarding the left hepatic artery, the proper hepatic artery was the source in 23 (76.7%) cases. In 2 (6.7%) cases, it originated directly from the left gastric artery. Left gastric and proper hepatic artery combined were the sources of origination of the LHA in 4 (13.3%) cases. CHA was observed in only 1 case (**Table 4**).

Table 4: Origin of hepatic artery

| Hepatic Artery                           | Frequency | Percentage |
|------------------------------------------|-----------|------------|
| <b>Right hepatic artery</b>              |           |            |
| Proper hepatic artery                    | 24        | 80.0%      |
| Superior mesenteric artery               | 3         | 10.0%      |
| Common hepatic artery                    | 1         | 3.3%       |
| Superior mesenteric artery and proper HA | 2         | 6.7%       |
| <b>Left hepatic artery</b>               |           |            |
| Left gastric artery                      | 2         | 6.7%       |
| Proper hepatic artery                    | 23        | 76.7%      |
| Common hepatic artery                    | 1         | 3.3%       |
| Left gastric and proper hepatic artery   | 4         | 13.3%      |

The gastroduodenal artery originated from CHA in 96.7% (n = 29) cases. However, in one case, trifurcation was found. RHA is the main source of cystic artery, reported in 86.7% (n = 26) of the cadavers. The proper HA was found to be the source of the cystic artery in 3 (10%) cadavers. Due to cholecystectomy, one cadaver had no cystic artery. (**Table 5**)

Table 5: Origin of the gastroduodenal and Cystic artery

| Artery                          | Frequency | Percentage |
|---------------------------------|-----------|------------|
| <b>Gastric Artery</b>           |           |            |
| Common hepatic artery           | 29        | 96.7%      |
| Common hepatic and trifurcation | 1         | 3.3%       |
| <b>Cystic artery origin</b>     |           |            |
| Right hepatic artery            | 26        | 86.7%      |
| Proper hepatic artery           | 3         | 10.0%      |
| Missing due to cholecystectomy  | 1         | 3.3%       |

#### 4. DISCUSSION

In the current study, we classified the variants of the HA in the South African population according to Michels's classification. In this study, we evaluated 30 cadavers. Type 1, where the hepatic trunk arises from CHA, was found in over half of the cases. Type 1 is considered normal, and other types are considered anomalies. Our study found normal configuration in 53.34% of the cadavers, and 46.66% reported anomalies. This finding is similar to the findings of the previous studies, ranging from 52% to 69.1%. (7, 9, 16, 17)

Our result ties well with a Turkish retrospective analysis of 100 patients who underwent MDCT angiography of the abdominal aorta aged 10–85 years. According to the Turkish study, Type 1 classification was found in 52% of cases. (16) In accordance with the current study's findings, in an Egyptian study conducted, over 1000 individuals reported that Type 1 configuration was highly prevalent. (7) Another descriptive, retrospective cross-sectional study performed in Pakistan reported that out of 110 patients, 69.1% had normal or Type 1 configuration. (17) Similarly, a similar pattern of results was obtained in a study performed in the West Indies, where CT scans were used to evaluate the HA configuration in 205 patients, showing 54.6% of individuals with typical Type 1 anatomy. (9) Contrary to the findings of our study, another investigation revealed 34.0% of patients with an abnormal hepatic arterial pattern. (18).

The most common anomaly in our study was Type

5. The current study found 10% of cases of Type 5. A study using CT-angiographies of 1297 individuals found 8.8% (n = 114) of Type 5 cases.(19) In one study, Type 5 was observed in 5.5% of cases.(20) On the other hand, a study performed in Egypt found only 1 case of Type 5 variation out of 500, which makes its prevalence 0.2%.(21) This disparity may be attributable to the small size of the auxiliary branches, resulting in an underestimate of these arteries on angiography. (22).

In our study, Type 3 variant was the second most common anomaly and was reported in 6.7% of the cases. Similar to the findings of our study, other studies also reported 6%, (23) 6.3 % (24) and 5.2% (20) cases of Type 3. However, according to Michel, this variation was found in 11 % of cases. (14) He reported that Type 3 is the most prevalent type of HA variation. (14) Another study also stated that Type 3 is the most common anomaly. (18).

In the current study, we observed that anomalies are more prevalent in Africans than Caucasians. A total of 52.4% of the Africans reported aberrant variants. On the other hand, only 33.3% of Caucasians reported aberrant variants. Racial dissimilarities were also observed in the previous study. A study on the Caribbeans stated that, even though the majority of individuals in a Caribbean community have conventional vascular anatomy, the distribution of arterial variations differs significantly from that observed in North American and European centers. (20).

Variations in the HA can occur due to a number of factors, including genetic factors and developmental abnormalities. HA variations are often asymptomatic and are often discovered during medical imaging tests or surgery. In most cases, HA variations do not cause any problems and do not require treatment. However, if an individual is experiencing symptoms or if a HA variation is causing complications, it may be necessary to seek medical attention and possibly undergo treatment. (25).

Arterial variations can be described based on embryology. Multiple malformations are caused by the development and regression of the ventral segmental arteries, which result in variations. The common HA typically originates as one of the three primary branches of the celiac axis during normal development. The origin of the RHA is the continuation of the CHA as the proper HA. There

are different anatomic variants of the hepatic arterial tree in adults due to the varied persistence of embryologic blood supply components.(26) A surgeon must be familiar with these variances to prevent unintended injuries during vessel management, ligation, clipping and division, and the related morbidity of surgery.

In the current study, anatomic variation was also observed in CHA. Around 13.3% of the cases reported anomalies, and 86.7% of the subjects showed typical patterns, namely, CHA originated from the CT. Our findings are relevant to the previous studies that reported that CHA typically originates from the CT.(16, 27) .

One of the primary limitations is the limited availability of cadavers. Furthermore, this study was conducted at a single location, which limits its ability to accurately reflect the whole population and provide a comprehensive understanding of the frequency and underlying factors of HA differences. Given the limited sample size, the likelihood of both type 1 and type 2 errors is elevated. Furthermore, a significant drawback is the inability to achieve reliable statistical significance due to the limited sample size, which necessitates considering this work as a pilot.

Extensive investigation is needed to understand the prevalence and causes of HA variations. Multiple universities may collaborate on these initiatives to study a research topic. Imaging or computer modelling can be used to study human anatomy without cadavers. These technologies provide detailed data on the HA's structure and function, helping researchers understand the underlying causes affecting this major artery.

## 5. CONCLUSION

Our investigation demonstrated that variances existed in nearly half of the cadavers examined using the Michels's classification. Type 9 and Type 5, each accounting for 10%, were the most prevalent variations. To reduce problems and improve results, it is important for surgeons practicing in this field to be aware of this fact and plan for it before performing surgery on patients.

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