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Anatomical Variants of the Hepatic Artery and Portal Vein on CT-Scan in Two Cities in Cameroon

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Abstract

Background: Anatomical variants are common in hepatic vasculature. They have gained clinical relevance with the expansion of laparoscopic surgery, living donor transplantation, and interventional radiology, where unrecognized patterns may increase perioperative risk. Emerging evidence suggests that the prevalence and distribution of vascular variants may vary across populations and geographic regions. **Objective**: This study aimed to determine the prevalence and characterize the types of anatomical variants of the hepatic artery and portal vein in patients undergoing imaging in Douala and Yaoundé, Cameroon. **Methodology**: This cross-sectional study involved the review of multiphasic thoracoabdominopelvic (TAP) and abdominal computed tomography (CT) examinations performed between September 1 and December 31, 2024, in three radiology departments located in Douala and Yaoundé. Eligible CT scans with at least arterial and portal venous phases were assessed for variants in hepatic artery and portal vein anatomy. Data were analyzed using SPSS version 23. Statistical significance was set at a p-value < 0.05. **Results**: In our sample of 439 patients, there was a male-to-female ratio, 1:1.8 and the mean age was 51.6 +/− 16.2 years. We analyzed 420 scans for hepatic artery anatomy and 413 scans for portal vein anatomy. Variant hepatic artery anatomy was observed in 45.2% of the population, with the Michel types V, II and III being the most common (18.1%, 11.0% and 5.2% prevalence respectively). Variants in the portal vein were observed in 24.5%, with the separate branch of the right portal vein (RPV) and trifurcation of the main PV being the most common variants (14.6% and 7.7% prevalence respectively). No association with gender was observed. **Conclusion**: Hepatic vascular variants exist in the Came-

roonian population with a similar prevalence to those described in the literature. However, there is some difference in the variants of hepatic artery and portal vein anatomy. These findings support routine preoperative vascular mapping to guide hepatic surgery and interventional procedures.

Keywords

Anatomic Variant, Hepatic Artery, Portal Vein, CT-Scan, Cameroon

1. Introduction

An anatomical variant refers to a normal aspect of body structure with different morphological features from the most commonly described anatomy [1]. These usually result from developmental errors during the embryological phase and have been described in all organs and vascular beds, including the liver and kidneys. Earlier studies on these variants were almost entirely cadaveric but they still gave a basis on which further research could be based.

In recent times, innovations in medical practice have led to an increase in the rates of procedures such as interventional radiology, transplantation and laparoscopic surgeries [2] [3]. These procedures have evolved rapidly, especially in the case of transplantation where live donors are currently more commonly used than cadaveric donors. Also, in cases of penetrating abdominal trauma, adequate management requires proper assessment of the type of damage incurred, with vascular injuries being the most severe injuries observed [4] [5]. In addition, aberrant vessels increase the chances of iatrogenic injury during surgical procedures. As such, a good pre-therapeutic workup requires in-depth understanding of the vascularization of the organs involved and a search for any variations which could potentially alter management strategies in real time and in living patients [3] [6] [7].

In order to assess these vascular variants, several methods have been used, including digital subtraction angiography (DSA) in living subjects [8] and visual inspection in cadavers [9]-[12]. Digital subtraction angiography, which has both diagnostic and therapeutic aims, is considered the gold standard. However, its invasive nature limits its use in current practice [8]. Recently, with the advent of multi-detector computed tomography (MDCT), the normal anatomy of small vessels and their variants can be well demonstrated in a non-invasive manner [13] [14].

Earlier studies showed that, in the liver, hepatic arterial variants are present in about half of the population [15]-[17] while portal venous variants could be found in 20% - 40% of the population [18]. These results reflect the variations in the populations studied and there is evidence that there is a geographical difference in the prevalence or type of variants observed in those studies [19].

Several studies in high-income countries have evaluated the prevalence of hepatic vascular anatomical variants using digital subtraction angiography (DSA),

the reference standard, and have demonstrated their impact on surgical planning. In Cameroon, DSA is available in only two centres. However, hepatic oncologic surgery is increasingly performed, and interventional radiology has been initiated in a referral hospital, underscoring the need to recognize hepatic vascular variants. Determining their prevalence in the general population would therefore provide clinically relevant data.

This study aimed to determine the prevalence and characterize the types of anatomical variants of the hepatic artery and portal vein in patients undergoing imaging in Douala and Yaounde, Cameroon. The availability of these data will contribute to optimizing preoperative planning, potentially reducing operative time and minimizing the risk of intraoperative complications during hepatic surgery.

2. Patients and Methods

2.1. Study Design and Setting

We conducted a cross-sectional study in three hospitals located in two major cities in Cameroon, Yaoundé and Douala. In Yaoundé, data were collected from one tertiary referral hospital, Yaoundé General Hospital (YGH), and one private imaging centre, Centre Médical La Cathédrale (CMC). In Douala, data were obtained from one tertiary referral hospital, Laquintinie Hospital Douala (LHD).

The CT equipment available at the participating centers were as follows:

- LHD: Siemens SOMATOM Perspective (128-slice);
- YGH: Siemens SOMATOM Go.Top (64-slice);
- CMC: Toshiba Aquilion (128-slice).

2.2. Study Population

The study population comprised all patients who underwent thoraco-abdomino-pelvic (TAP) or abdominal CT examinations, irrespective of indication, between September 1 and December 31, 2024. Patients were eligible if they had undergone multiphasic TAP or abdominal CT with, at minimum, acquisition of both arterial and portal venous phases.

Exclusion criteria included major anatomical distortion (e.g., hepatic masses altering vascular anatomy, advanced cirrhosis with marked architectural distortion), inadequate vascular enhancement (severe motion artifacts affecting vascular visualization, poor contrast bolus timing with absence of clearly visible arterial or portal venous enhancement), technical failure of bolus tracking, incomplete coverage of the anatomical regions of interest, and repeat CT examinations in the same patient during the study period.

Data were collected consecutively and exhaustively. All examinations meeting the inclusion criteria were included in the analysis.

2.3. Data of Interest

The data of interest included socio-demographic and radiologic variables. Socio-

demographic characteristics comprised age and sex.

Radiologic evaluation focused on the hepatic arteries and portal vein with systematic identification and classification of anatomical variants.

For the hepatic arterial system, the origin of the common hepatic artery (CHA) was documented (celiac trunk, aorta, superior mesenteric artery [SMA], celiacomesenteric trunk, left gastric artery, or other). The number and origin of the right hepatic artery (RHA) and left hepatic artery (LHA) were recorded, including accessory or replaced branches (e.g., RHA arising from the SMA or LHA from the left gastric artery). Combined variants, the presence and origin of the middle hepatic artery, and other unclassified patterns (e.g., double hepatic artery, replaced hepatic artery proper from the SMA) were also assessed. Hepatic arterial anatomy was ultimately categorized according to the Michel's classification that describes 10 patterns of hepatic arterial anatomy based on the origin of the right and left hepatic arteries. Type I corresponds to classic anatomy, with the common hepatic artery arising from the celiac trunk and dividing into right and left hepatic arteries. Variants include replaced or accessory left hepatic artery from the left gastric artery (types II and V), replaced or accessory right hepatic artery from the superior mesenteric artery (types III and VI), combined replaced or accessory patterns (types IV, VII, and VIII), and anomalous origin of the common hepatic artery from the superior mesenteric artery (type IX) or left gastric artery (type X). The classification distinguishes between "replaced" arteries, which substitute the normal branch, and "accessory" arteries, which coexist with it [15]. Any hepatic arterial pattern that did not strictly correspond to one of Michels' classification types was categorized as "unclassified".

For the portal venous system, the level of division (intrahepatic or extrahepatic) and the number of main branches were recorded. Specific branching patterns were documented according to the Covey classification [20], including the classical anatomy (type 1: main portal vein dividing into right and left portal veins, with right anterior and posterior branches arising from the right portal vein), right posterior portal vein as the first branch of the main portal vein (type 3), and separate segmental branches from the right portal vein to segment VII (type 4) or segment VI (type 5). Any portal vein pattern that did not strictly correspond to one of Covey classification types was categorized as "unclassified".

2.4. Scanning Protocol

A standardized multiphasic CT protocol was applied. Examinations were performed with the patient in the supine position, arms elevated, and the abdomen centered within the gantry. Tube voltage was ≤120 kVp, with tube current modulated using automatic exposure control.

Scanning extended from above the diaphragm to the pelvis, depending on the indication. The arterial phase typically covered the diaphragm to the iliac crest, while the portal venous phase extended from above the diaphragm to the symphysis pubis. Acquisition was performed in a craniocaudal direction.

Images were acquired with a field of view of approximately 350 mm (adjusted as needed), slice thickness ≤ 0.75 mm, and reconstruction interval ≤ 0.5 mm, using both soft tissue and bone algorithms.

Following an optional unenhanced acquisition, contrast-enhanced imaging was performed using 70 - 100 mL of iodinated contrast (approximately 0.1 mL/kg) administered at 3 - 5 mL/s, followed by a 30 - 40 mL saline flush. Bolus tracking was placed in the abdominal aorta. The arterial phase was acquired with minimal delay, and the portal venous phase at 60 - 80 seconds after contrast injection.

All acquisitions were performed during a single inspiratory breath-hold. Multiplanar reconstructions (axial, coronal, and sagittal) were systematically generated, with reconstructed slice thickness of 4 - 5 mm for soft tissue using 20% - 40% overlap.

2.5. Image Interpretation

CT examinations were reviewed on site using the available dedicated workstations and DICOM viewers at each center. Scans from Yaoundé General Hospital (YGH) were analyzed using the Siemens SOMATOM Workstation® software and the Carestream DICOM® viewer. Examinations from Centre Médical La Cathédrale (CMC) were reviewed with EvoluView® and Weasis® DICOM readers, while those from Laquintinie Hospital Douala (LHD) were assessed using the RadiAnt® DICOM viewer.

All images were simultaneously reviewed and interpreted by a radiologist and a radiology assistant, with findings recorded by consensus.

2.6. Statistical Analysis

Data were collected using Google Forms and exported to Microsoft Excel 2010 for initial data management. The dataset was subsequently transferred to IBM SPSS Statistics version 23 for statistical analysis.

Quantitative variables were summarized as means ± standard deviations (SD), and categorical variables as frequencies and proportions (%), presented in tables. Associations between categorical variables were assessed using the chi-square test. Statistical significance was defined as a two-sided p-value < 0.05.

2.7. Ethical Considerations

Ethical approval was obtained from the Institutional Review Board of the Faculty of Medicine and Biomedical Sciences, University of Yaoundé I (Approval No. 0171/UY1/FMSB/VDRC/DAASR/CSD/emr).

3. Results

A total of 504 patients were initially enrolled. After image review, 65 (12.9%) were excluded due to inadequate vascular enhancement or large masses obscuring vascular anatomy. The final analysis included 439 patients: 173 from YGH, 95 from CMC, and 171 from LHD.

3.1. Socio-Demographic Characteristics of the Study Population

The study population comprised 153 males and 286 females (male-to-female ratio, 1:1.8). Participants ranged in age from 4 to 95 years (mean 51.7 ± 16.3 years). Most patients were aged 41 - 60 years (205/439, 46.7%) (Figure 1).

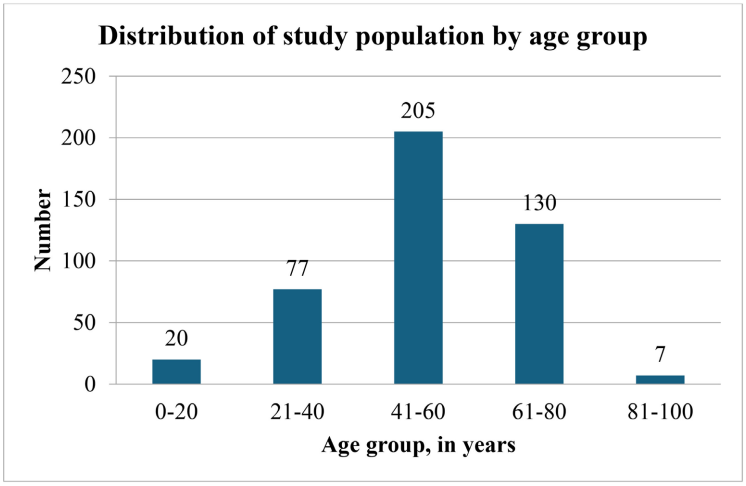

Figure 1. Age distribution of the study population.

3.2. Prevalence of Hepatic Artery and Portal Vein Anatomical Variants

Because of suboptimal vascular enhancement in some examinations, hepatic arterial anatomy was analysed in 420 patients and portal venous anatomy in 413 patients. Hepatic.

Among the 420 patients in whom hepatic arterial anatomy was assessable, standard anatomy was observed in 230 (54.8%, 95% CI: 50.0 - 59.5), whereas 190 (45.2%, 95% CI: 40.5 - 50.0) demonstrated variant patterns.

The prevalence of hepatic arterial variants was similar across the three study sites. Variant rates were 46.5% at YGH, 46.8% at CMC, and 42.9% at LDH. The inter-site comparison showed no statistically significant difference ($p = 0.756$), indicating that the observed variations are consistent across centres (Table 1).

Table 1. Hepatic artery variant prevalence by site.

	Total	Hepatic Arteries analyzed	Variant (n)	Variant % (95% CI)
YGH	173	172	80	46.5% (39.2 - 54.0%)
CMC	95	94	44	46.8% (37.0 - 56.8%)
LDH	171	154	66	42.9% (35.3 - 50.8%)
Overall	439	420	190	45.2% (40.5 - 50.0%)

Inter-site chi square: $X^2 = 0.559$, $P = 0.756$.

Of the 413 patients evaluated for portal venous anatomy, 312 (75.5%, 95% CI: 71.2 - 79.4) had standard anatomy and 101 (24.5%, 95% CI: 20.6 - 28.8) exhibited anatomical variants.

The prevalence of portal venous variants showed moderate variation across sites, ranging from 20.9% at YGH to 29.8% at CMC, with LDH at 24.8%. Despite these differences the inter-site comparison did not reach statistical significance (p = 0.280) (Table 2).

Table 2. Portal vein variant prevalence by site.

	Total	Portal veins analyzed	Variant (n)	Variant % (98% CI)
YGH	173	158	33	20.9% (15.3 - 27.9%)
CMC	95	94	28	29.8% (21.5 - 39.7%)
LDH	171	161	40	24.8% (18.8 - 32.1%)
Overall	439	413	101	24.5% (20.6% - 28.8%)

Inter-site chi square: $X^2 = 2.549$, P = 0.280.

3.3. Description of Hepatic Artery Variants

Hepatic arterial anatomy was analyzed in 420 patients and classified according to the Michels classification (Table 3). Of the 10 variants described by Michel, nine (9) were identified in this study. The most frequent variants were type V (76/420, 18.1%), type II (46/420, 10.9%), and type III (22/420, 5.2%) (Figure 2, Figure 3).

Table 3. Michel's classification of hepatic arterial anatomy.

Description	Number of cases, n = 420	Frequency, %
Michel's classification		
Type I: Normal anatomy	230	54.8
Type II: Replaced LHA from LGA	46	10.9
Type III: Replaced RHA from SMA	22	5.2
Type IV: Replaced LHA and replaced RHA	4	1.0
Type V: Accessory LHA from LGA	76	18.1
Type VI: Accessory RHA from SMA	3	0.7
Type VII: Accessory RHA from SMA and accessory LHA from LGA	2	0.5
Type VIII: Replaced RHA and accessory LHA *OR* replaced LHA and accessory RHA	7	1.7
Type IX: CHA from SMA	4	1.0
Type X: CHA from LGA	0	0.0
Unclassified	18	4.3
Combinations		
Type I + unclassified	3	0.7
Type II + unclassified	1	0.2
Type III + unclassified	1	0.2
Type V + unclassified	3	0.7

*LHA: left hepatic artery. LGA: left gastric artery. RHA: right hepatic artery. SMA: superior mesenteric artery. CHA: common hepatic artery.

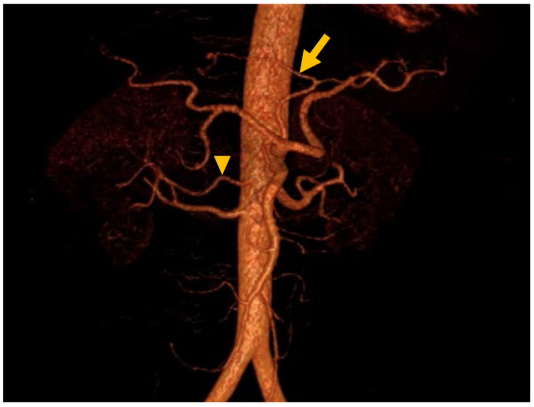

Figure 2. Volume rendering of a replaced LHA from the left gastric artery (arrow)—Michels' Type V—Note presence of an accessory right renal artery (arrowhead).

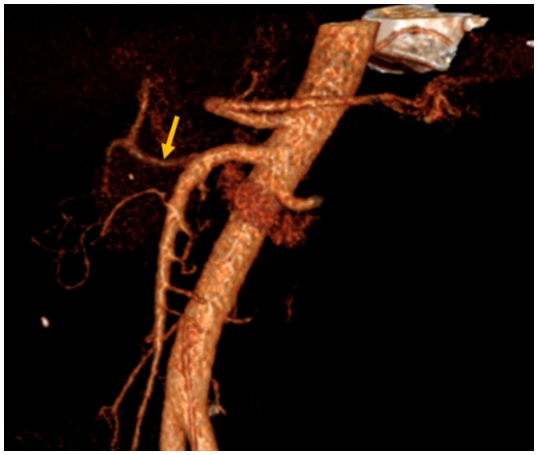

Figure 3. Volume rendering illustrating the CHA from the superior mesenteric artery—Type IX.

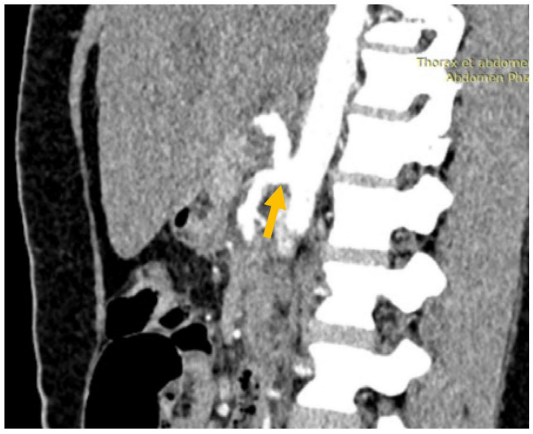

Figure 4. Sagittal reconstruction image showing a celiaco-mesenteric trunk.

Eighteen patients exhibited hepatic arterial configurations that could not be assigned to any Michels type and were categorized as unclassified (Table 3). These included the presence of a celiaco-mesenteric trunk in 7 patients (Figure 4) and a

double hepatic artery in 1 patient. Additional anomalous origins of the right hepatic artery were observed, arising from the celiac trunk in 11 patients (Figure 5), from a celiaco-mesenteric trunk in 1 patient, from the aorta in 1 patient, and from the common hepatic artery in 2 patients. Anomalous origins of the left hepatic artery from the celiac trunk (1 patient) and from the common hepatic artery (1 patient) were also identified. These variants were included in the overall prevalence of hepatic arterial variants but reported separately as they could not be mapped to a specific Michels type.

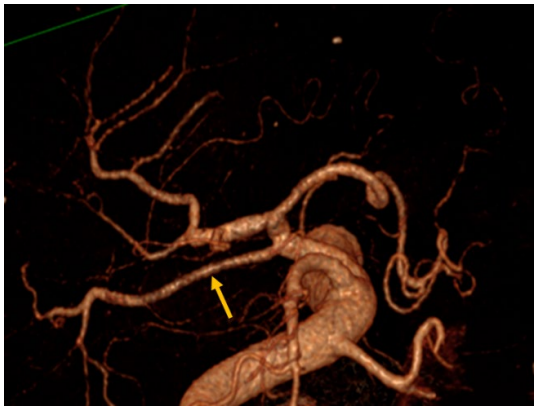

Figure 5. Volume rendering of a RHA arising directly from the celiac trunk (also presence of a middle hepatic artery).

3.4. Description of Portal Vein Variants

Of the 413 CT examinations analyzed for portal venous anatomy, 312 (75.5%) had the normal anatomy. According to Covey's classification, the most frequent variant was a separate right posterior portal vein branch to segment VI (49/413, 11.9%) (Table 4).

Table 4. Covey classification of portal vein anatomy.

Type of variant	Number of cases, n = 413	Proportion, %
Type I: Classical anatomy	312	75.5
Type II: Trifurcation of main PV	32	7.7
Type III: RPPV as first branch of main PV	2	0.5
Type IV: Separate branch of RPV to segment VII	11	2.7
Type V: Separate branch of RPV to segment VI	49	11.9
Unclassified	7	1.7

*PV: portal vein. RPPV: right posterior portal vein. RPV: right portal vein.

Unclassified variants included quadrifurcation of the right portal vein, quadrifurcation of the main portal vein, and an atypical bifurcation in which the main portal vein divided into the right anterior and right posterior branches, with the

left portal vein arising from the right anterior branch.

3.5. Correlation between Vascular Variants and Gender

Among the 420 patients evaluated for hepatic arterial anatomy, standard anatomy was observed in 89 males (21.2%) and 141 females (33.6%), whereas variant anatomy was identified in 59 males (14.0%) and 131 females (31.2%). Although hepatic arterial variants were more frequently observed in females than in males, this difference was not statistically significant ($p = 0.1$).

Among the 413 patients assessed for portal venous anatomy, normal anatomy was identified in 106 males (25.7%) and 206 females (49.9%), whereas variant patterns were observed in 37 males (9.0%) and 64 females (15.5%). Although portal venous variants appeared more frequent in males, the difference was not statistically significant ($p = 0.71$).

There was also no observed correlation between portal venous and hepatic arterial variants ($p = 0.277$).

4. Discussion

The aim of this study was to determine the prevalence and characterize the types of anatomical variants of the hepatic artery and portal vein in patients undergoing imaging in Douala and Yaoundé, Cameroon. In our study of 439 Cameroonian patients, the prevalence of hepatic arterial variants was 45.2%, while portal venous variants were identified in 24.5% of cases.

4.1. Hepatic Artery Variants

Regarding the hepatic arterial vasculature, normal anatomy was described as a CHA arising from the celiac trunk (which itself arose directly from the abdominal aorta) and giving off the proper hepatic artery and the gastroduodenal artery. The proper hepatic artery then had to bifurcate into the left and right hepatic arteries. Any variation of this pattern was termed an aberrant artery [15]. After analyzing 420 hepatic arterial systems, normal anatomy was seen in 54.8% of the population according to Michel's classification, with variants accounting for 45.2%. This was similar to the original study carried out by Michel *et al.* in 1966 on cadavers [15], Muzenda in 2020 in South Africa [20] and Cawich *et al.* in 2021 in Trinidad and Tobago [17], who had a prevalence of 55%, 55% and 54.6% for normal anatomy respectively. However, this was lower than what was described in 2 systematic reviews by Löschner *et al.* in 2015 [21] and Noussios *et al.* in 2017 [22], with a prevalence of 72.2% and 81% respectively. This difference could be explained by the larger sample sizes in their studies (1297 and 19,103 patients respectively) compared to our sample of 420 patients analyzed for hepatic arterial anatomy. Also, their studies were systematic reviews assessing populations with different genetic backgrounds, eliminating any population-related bias.

Based on Michel's classification, the most common hepatic arterial variant in our study was the accessory LHA from the left gastric artery (type V) with a prev-

alence of 18.1%. This variant was also the most common described by Muzenda [20], with a prevalence of 12.7%. However, this was in contrast to the studies carried out by Michel [15], Sambath [3], Fonseca-Neto [23] and Noussios [22], who had the type II variant (replaced LHA from left gastric artery) as the most common. This could be explained by the fact that Muzenda's and our studies were based on sub-Saharan African populations (South Africa and Cameroon respectively), further supporting the theory that patterns of vascular variants are diverse probably due to genetic differences in different populations.

The types II (replaced LHA from left gastric artery) and III (replaced RHA from the superior mesenteric artery) variants were the next most common variants in our study, accounting for 11.0% and 5.2% respectively. The fact that the most common variants observed were both the accessory and replaced LHA from the left gastric artery (types V and II respectively accounting for 29.1% of all variants) signals the importance of verifying hepatic vasculature before gastric-related procedures in our context.

The type X variant (entire hepatic trunk arising from the left gastric artery) was not found in any of the patients. This is consistent with other studies like those of Sambath [3], Cawich [17] and Zaki [24]. Since it was described by Adachi in 1928 [25], only a handful of cadaveric and angiographic studies/case reports have described this variant in detail [26] [27], revealing it to be a rare variant overall.

4.2. Portal Vein Variants

Portal venous anatomy was analyzed in 413 patients. Standard anatomy usually comprises bifurcation of the main portal vein (PV) at the hepatic hilum into LPV and RPV, with further bifurcation of the RPV into the RAPV and RPPV. This normal anatomy was observed in 75.5% of the study population, similar to that seen by Sureka *et al.* in 2015 [28] and Ulusoy *et al.* in 2020 [29]. They reported prevalences of 79.94% and 82.6% respectively. However, it was higher than in the studies by Covey [18] and Sambath [3], who showed a prevalence of 65% and 57.4% respectively. This difference could be explained by the relatively low sample sizes in the latter studies (200 and 350 patients respectively).

The most common portal vein variant in our study was the type V (separate branch of RPV to segment VI) seen in 11.9% of our study population, followed by trifurcation of the main PV in 7.7%. The type V variant was one of the least observed in the above studies, in which the type II (main PV trifurcation) was the most common variant followed by type III (RPPV as first branch of main PV).

4.3. Association between Vascular Variants and Gender

No significant association was found between patient gender and the presence of portal venous variants ($p = 0.71$), consistent with previous reports by Ulusoy [29] and Sambath [30]. Similarly, hepatic arterial anatomy was not associated with gender ($p = 0.1$). This could be explained by the fact that there is no known

embryological pathway involving both the hepatic vascular and the genital systems.

4.4. Study Limitations

This study has some limitations. Its retrospective design may have introduced selection bias and limited control over imaging protocols across centers. A proportion of examinations were excluded because of suboptimal vascular enhancement, potentially affecting representativeness. Although multicentric, the study was hospital-based and may not fully reflect the general population. Finally, the use of CT rather than digital subtraction angiography, the reference standard, may have limited the detection of subtle vascular variants. Nevertheless, the study included a multicenter sample from two major urban settings and reflects real-world imaging practice. Moreover, multiphasic CT is the modality most used for preoperative planning in this context, making the findings directly applicable to surgical and interventional decision-making.

5. Conclusions

In this multicenter cross-sectional study conducted in two major Cameroonian cities, hepatic vascular anatomical variants were common. Nearly half of the evaluable patients (45.2%) demonstrated hepatic arterial variants, while portal venous variants were observed in 24.5% of cases. According to Michels' classification, accessory or replaced hepatic arteries—particularly type V (accessory left hepatic artery from the left gastric artery), type II, and type III—were the most frequent patterns. Portal venous anatomy was predominantly classical (75.5%), with the most common variant being an independent right posterior portal vein branch to segment VI.

Several unclassified and rare variants were also identified, highlighting the anatomical diversity of hepatic vasculature in this population. No statistically significant association was found between vascular variants and gender.

These findings underscore the high prevalence and heterogeneity of hepatic vascular variants in the studied population and support the systematic preoperative evaluation of hepatic arterial and portal venous anatomy to optimize surgical and interventional planning.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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