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Original Research Article

Anatomic variations of the hepatic arterial irrigation in a Mexican population: contrast enhanced computer tomography evaluation: a cross-sectional study

Daniel Benito Castillo-Martínez*, Doris Michelle Palacios-Rivera, Jorge Boy-Serratos

General Surgery Department, North Central PEMEX Hospital, Mexico City

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***Correspondence:**
Dr. Daniel Benito Castillo-Martínez,
E-mail: drdancastillo@icloud.com

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ABSTRACT

Background: Knowledge and mastery of the anatomical variability of the hepatic arteries are essential for surgical disciplines and, given their complexity and importance over time, they have been extensively studied and described.
Methods: A retrospective, cross-sectional, analytical study was carried out in which contrast-enhanced computer tomography (CT) studies carried out between January 2021 and December 2021 at the North Central PEMEX hospital were analyzed. A total of 207 contrast-enhanced CT scans were analyzed, and Statistical analysis was performed with the statistical software IBM® SPSS© Statistics.
Results: Uflacker type I CT was found in 90.8%, the Michel class I hepatic arterial irrigation in 70.5%, and the origin of CA was documented in the right hepatic arteries (RHA) in 90.3%. Multiple cystic artery (Cas) were identified in 1% and Moynihan's hump in 0.5%. The mean length of the common hepatic artery (CHA) was 53 millimeters.
Conclusions: The tomographic study of the anatomical variants of hepatic irrigation is an accessible and non-invasive tool. The nomenclature described in the present work allows a precise and straightforward understanding of clinical-surgical utility.

Keywords: Anatomy, Arteries, CT, Liver

INTRODUCTION

Knowledge and mastery of the anatomical variability of the hepatic arteries is essential for surgical disciplines and, given their complexity and importance over time, they have been extensively studied and described. The first formal description of its variability was made by the anatomist Albrecht von Haller in his book "Iconum anatomicarum quibus praecipuae partes corporis humani delineate continentur" published in 1756, however, it was not until 1928 that the illustrious Japanese anatomist Buntaro Adachi in his book "Das Arteriensystem der Japaner" described the frequency of its variability in a long series of autopsies, on the other hand, the radiological description using selective arteriographies was published in 1967 by Dr. Anders Lunderquist.[1] The embryological theoretical basis of this variability was exposed by Dr. Julius Tandler in 1904, where he proposed that these variants are the result of alterations in the development and migration of the ventral aortic branches from which the CHA, the left gastric artery (LGA) and the splenic artery (SA) originates.[2]

The need to group this information had a response in the classification proposed by Dr. Nicolas Michel who, after more than two decades of anatomical studies, published in 1966 the internationally recognized classification widely used for three decades, until in 1994 Dr. Jonathan R. Hiatt modified and simplified the classification established by Michel for its application in the planning and performance of surgical and radiological procedures of the upper abdomen.[3,4]

The classic description of the hepatic arterial anatomy is a CHA originating from the celiac trunk (CT), and after the origin of the gastroduodenal artery (GDA) it is called the hepatic artery proper (HAP) which branches into the right (RHA) and left (LHA) hepatic arteries. The CT has its origin in the anterior face of the aorta at the level of the lower border of the twelfth thoracic vertebra and the upper border of the first lumbar vertebra with a diameter of 4.6 to 12 millimeters and an average of 7.3 millimeters.[5,6] The CT posterior to its origin takes an anterolateral direction and at the level of the upper edge of the pancreas it trifurcates into: CHA, LGA and SA. The CHA runs laterally with a brief retroperitoneal path to the intersection of the upper border of the pancreas with the medial border of the common hepatic duct, the first branch of the CHA is the GDA, which gives rise to the superior pancreaticodudodenal artery (SPA) and the right gastric artery (RGA), which supply the first portion of the duodenum, head of the pancreas, and pylorus. From the emergence of the GDA, the CHA is called HAP, which takes a cephalad and lateral direction adjacent to the bile duct to the hepatic hilum, giving rise to LHA and the RHA, from where it originates to cystic artery (CA), responsible for the irrigation of gallbladder.

This anatomical arrangement of the hepatic irrigation is present in approximately 70% of cases.[7,8] CA originates from the RHA in 70-90% of cases.[9,10] The Michel and Hiatt classifications describe the variants in hepatic irrigation. The Uflaker classification describes the anatomical variants of the celiac trunk.[11]

Objective

Objectives of the study was to describe the anatomical variability of liver irrigation in a Mexican population and to correlate the findings with the most used classifications in current medical literature.

METHODS

Study design

A single center, retrospective, cross-sectional, analytical study was carried out in which the abdominal contrast-enhanced tomographic studies performed with the Phillips Incisive CT® scanner, abdominal aorta contrast protocol 1 millimeter cuts with low osmolality nonionic iopalmidol (0.796 osm/kg) at the North Central PEMEX hospital between January 2021 and December 2021, patients with contrast allergies and history of any surgical procedures on upper abdominal cavity were excluded, a total of 207 contrast-enhanced tomographic studies were analyze. The arterial phase was reconstructed and evaluated in coronal, sagittal and axial reconstructions by Imaging and Radiology department to describe the vascular structures of the hepatic arterial supply. Measurement of the CHA in multiplanar reconstruction was performed. Arterial structures were defined according to the classic anatomical description. For the description of the findings, the classifications of Michel (Table 1), Hiatt (Table 2) and, in the case of CT, the Uflacker classification (Table 3) were established, along with the nomenclature proposed in this study (Table 4), in which the origin and arrangement of the arterial structures of the hepatic irrigation are described in a simple and clear way. It is structured from left to right starting with the CHA, which is expressed with the letter "C", followed by the number that specifies its origin. The second letter represents the RHA expressed with the letter "R", followed by the number that corresponds to the origin and in case of the presence of an accessory or ectopic branch, the letters "ra" and "re" are added, respectively, ending with the description of the LHA expressed with a letter "L" and the number in the same way.

Table 1: Michel classification: anatomical variants of the hepatic artery.[3]

Class	Description
I	Origin of the CHA on the CT and the HAP bifurcates into the RHA and the LHA.
II	Origin of the CHA on the CT. Origin of the RHA on the HAP. Ectopic IAH originating from the LGA.
III	Origin of the CHA on the CT. Origin of the LHA on the HAP. Ectopic RHA originating from the SMA.
IV	Origin of the CHA on the CT. HAP, RHA and LHA. Accessory LHA originating from the LGA and accessory RHA originating from the SMA, ectopic RHA originating from the SMA.
V	Origin of the CHA on the CT. HAP, RHA and LHA. Accessory LHA originating from the LGA.
VI	Origin of the CHA on the CT. HAP, RHA and LHA. Accessory RHA originating from the SMA.
VII	Origin of the CHA on the CT. HAP, RHA and LHA. Accessory RHA originating from AMS. Accessory LHA originating from LGA.
VIII	Origin of the CHA on the CT. HAP and LHA. Accessory LHA originating from LGA. Ectopic RHA originating from the SMA.
IX	Origin of the CHA on the SMA. HAP, RHA and LHA.
X	Origin of the CHA on the AGI. HAP, RHA and LHA.

CHA: common hepatic artery, HAP: hepatic artery proper, RHA: right hepatic artery, LHA: left hepatic artery, LGA: left gastric artery, SMA: superior mesenteric artery.

Table 2: Hiatt classification: anatomical variants of the hepatic artery.[4]

Type	Description
I	Origin of the CHA on the CT and the HAP bifurcates into the RHA and the LHA.
II	Origin of CHA on the CT. Origin of RHA on the HAP. Ectopic/accessory LHA originating from LHA.
III	Origin of the CHA on the CT. Origin of the LHA on the HAP. Ectopic RHA originating from the SMA. / Origin of the CHA on the CT. HAP, RHA and LHA. Accessory RHA originating from AMS
IV	Origin of the CHA on the TC. HAP, RHA and LHA. Accessory LHA originating from the LGA and accessory RHA originating from the SMA, ectopic RHA originating from the SMA. / Origin of the CHA on the CT. HAP, RHA and LHA. Accessory RHA originating from the SMA. Accessory LHA originating from the LGA. / Origin of the CHA on the CT. HAP and LHA. Accessory LHA originating from the LGA. Ectopic RHA originating from the SMA.
V	Origin of the CHA on the SMA. HAP, RHA and LHA.
VI	Origin of the CHA on the Ao. HAP, RHA and LHA.

Ao: aorta, CHA: common hepatic artery, HAP: hepatic artery proper, RHA: right hepatic artery, LHA: left hepatic artery, LGA: left gastric artery, SMA: superior mesenteric artery.

Table 3: Uflacker classification: anatomical variants of the celiac trunk.[9]

Type	Description
I	Classic celiac trunk.
II	Hepatosplenic trunk.
III	Hepatogastric trunk.
IV	Hepatosplenomesenteric trunk.
V	Gastrosplenic trunk.
VI	Celio-mesenteric trunk-
VII	Celio-colic trunk.
VIII	Absence of celiac trunk.

Table 4: Simplified nomenclature of anatomical variants of hepatic arterial irrigation.

Reference coding	Description	Source coding	Description
C	CHA	1	Celiac trunk
		2	Superior mesenteric artery
		3	Aorta
R **ra** **re**	Right hepatic artery Accessory Ectopic	1	Hepatic artery proper
		2	CHA
		3	Superior mesenteric artery
		4	Aorta
L **la** **le**	Left hepatic artery Accessory Ectopic	1	Hepatic artery proper
		2	CHA
		3	Left gastric artery
		4	Aorta

The nomenclature is expressed from right to left (C-R-L), naming the reference arterial structure coding followed by the origin coding, if it does not exist, it is omitted and if an accessory or ectopic stricture exists, it is added in the corresponding order.

Statistical analysis was performed with the statistical software IBM® SPSS© statistics.

The protocol was approved by a central ethics committee, permission: DCAS-SSS GSM-HCN-INV-029-2022. The study was conducted in consistent with the declaration of Helsinki, informed consent obtained from all enrolled participants. Patient anonymity was preserved rigorously.

RESULTS

The 207 contrast-enhanced computer tomography scans in arterial phase were analyzed, of which 86 correspond to male patients (41.5%) and 121 to female patients (58.5%) between 11 and 94 years old with a median age of 62 years and a mode of 58 years.

The CT was documented with a classic Uflacker type I configuration in 188 patients (90.8%), 2 type III (1%), 15 type V (7.2%), one type VI and VIII (0.5%). The origin of the CHA was found in the CT in 175 patients (84.5%), 28 in the superior mesenteric artery (SMA) (13.5%) and 4 in the aorta (1.9%). The origin of the RHA was found in the HAP in 205 patients (99%) and in the CHA in 2 (1%). The LHA was found to be absent in 3 patients (1.4%), its origin was identified in 202 patients in the HAP (97.6%) and 2 patients in the CHA (1%). One patient with ectopic right hepatic artery (0.5%) and 17 patients with accessory right hepatic artery (8.2%) were identified, both from the SMA. On the other hand, 2 patients presented ectopic left hepatic artery (1%) and 30 patients had accessory left hepatic artery (14.5%), both with origin in the LGA. Variants in the general configuration according to Michel's classification were documented in 146 class I patients (70.5%), 10 class II (4.8%), 12 class VI (5.8%), 6 class VII (2.9%), one class VIII patient (0.5%), 28 class IX (13.5%) and 4 unclassifiable (1.9%). In the case of the Hiatt classification, 148 type I patients (71.5%), 10 type II (4.8%), 12 type III (5.8%), 7 type IV (3.4%), 28 type V (13.5%) and 2 type VI patients (1%) were documented (Table 5).

Table 5: Distribution of the found variants by classification.

Castillo	N (%)	Michel	N (%)	Hiatt	N (%)	Uflacker	N (%)
C1	175 (84.5)	Class I	146 (70.5)	Type I	148 (71.5)	Type I	188 (90.8)
C2	28 (13.5)	Class II	10 (4.8)	Type II	10 (4.8)	Type III	2 (1)
C3	4 (1.9)	Class VI	12 (5.8)	Type III	12 (5.8)	Type V	15 (7.2)
R1	205 (99)	Class VII	6 (2.9)	Type IV	7 (3.4)	Type VI	1(0.5)
R2	2 (1)	Class VIII	1 (0.5)	Type V	28 (13.5)	Type VIII	1(0.5)
L1	202 (97.6)	Class IX	28 (13.5)	Type VI	2 (1)	-	-
L2	2 (1)	Unclassifiable	4 (1.9)	-	-	-	-
ra3	17 (8.2)	-	-	-	-	-	-
re3	1 (0.5)	-	-	-	-	-	-
la	30 (14.5)	-	-	-	-	-	-
le	2 (1)	-	-	-	-	-	-

C: Common hepatic artery, R: Right hepatic artery, ra: right accessory, re: right ectopic, L: Left hepatic artery, la: left accessory, le: left etopic.

The origin of CA was documented in 187 patients in the RHA (90.3%), 16 in the accessory right hepatic artery (16%), 2 in DGA (1%), one patient in the SPA (0.5%), ectopic right hepatic artery (0.5%), 2 multiple CAs (1%) and a Moynihan hump (0.5%).

In the CHA measurement, a mean length of 53 millimeters was obtained (95% CI 51.13-54.86, SD 13.58), 51.11 millimeters (95% CI 48.79-53.44, SD 12.91) for females, and 55.65 millimeters (95% CI 52.62-58.67, SD 14.11) in males. Height was recorded in centimeters with a mean of 161.7 centimeters, a minimum of 135 centimeters and a maximum of 185 centimeters. CHA and height measurements showed normal distribution using the Kolmogorov-Smirnov test (sig>0.05). Significant difference in CHA length was observed between gender (t[205]=2.395, p=0.018). The Pearson correlation test showed a weak positive correlation between the length of the CHA as well as the height with a value of $r_{(207)}=0.062$, not significant (p=0.382).

DISCUSSION

Mastery of anatomical knowledge for surgical disciplines is a prerequisite for achieving the best probable results, in the case of the anatomical variability of the hepatic arterial supply, it is worth noting that angiography has been the gold standard for many years to identify its variations, being able to identify them in 60-80% of the cases, however, in recent years, the technological development of CT has allowed non-invasive visualization of abdominal vascular structures, allowing their variability to be identified with greater precision than angiography, because during angiographic studies it is especially difficult to differentiate between accessory and ectopic branches.[4,12,13] The incidence of anatomical variants of hepatic arterial irrigation in angiographic studies according to Michel's classification reports class I in 69.77% (80.3-52%), class II 6.7% (10-2.5%), class III 9.02% (15.5-3.5%), class IV 0.6% (1-0%), class V 2.62% (8-0%), class VI 2.98% (7-0.5%), class VII 0.4% (1-0%), class VIII 0.38% (2-0%), class IX 2.75% (4.5-1.4%), class X 0.07% (0.5-0%) and not classifiable 4.28% (14.7-0%).[3,14-19]

In the case of CA, its origin in the RHA has been reported in 87.74% (95.75-75.25%), accessory RHA 1.33% (8.02-0%), HAP 3.8% (9.52-0%), CHA 0.84% (4.76-0%), DGA 1.01% (4.76-0%) and multiple CAs were described in 11.2% (19.2-0%).[20-25] Recently, a retrospective study where 5625 patients who underwent tomographic studies and chemoembolizations were analyzed, reported a prevalence of accessory RHA of 15.63% and accessory LHA of 16.32%.[26] On the other hand, Moynihan's hump is a poorly described anatomical variant of the RHA, with an incidence of 1.3 to 13.33%.[27-29]

The large number of variations described in different studies over the years demonstrates the difficulty for the clinical-surgical use of the classifications described above, therefore, in this work, our own nomenclature shown in the Table 4 has been used in parallel to Michel and Hiatt's classification. This nomenclature allows a brief and precise description of the configuration in the hepatic arterial irrigation, with the aim of its simple and rapid clinical-surgical application.

Limitations

The principal limitation of this study is the sample size, results may not be generalized and further research is needed.

CONCLUSION

The tomographic study of the anatomical variants of the hepatic irrigation is an accessible and non-invasive tool. The nomenclature described in the present work allows an exact and simple understanding with clinical-surgical utility. The precise description of the anatomical variants of the hepatic irrigation is essential in bariatric, oncological, anti-reflux and hepato-pancreato-biliary surgical procedures since these variants may determine the need to adjust or modify the surgical plan.

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