PREVALENCE OF MICHEL'S TYPE 1 HEPATIC ARTERIAL ANATOMY ON CT ANGIOGRAPHY IN NEPALESE POPULATION

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ABSTRACT

Multidetector Computed Tomography (MDCT), with an accuracy of 95-100%, is the modality of choice for preoperative assessment of hepatic artery anatomy in this era of modern hepatic surgeries. Celiac trunk is the first anterior branch of the abdominal aorta and trifurcates into left gastric, splenic, and common hepatic artery which branches into gastroduodenal and proper hepatic artery which then divides into right, middle and left hepatic arteries. Superior mesenteric artery (SMA) originates from abdominal aorta one centimeter below the celiac trunk. This "classic" anatomy pattern is seen only in approximately 61.3% of patients. This study aims at establishing prevalence of hepatic artery anatomical variations on MDCT in Nepalese population since such study has not been published in context of Nepal yet. Cross-sectional descriptive study was performed on MDCT images of all patients undergoing CT abdomen and pelvis with angiography between November 2018 and October 2022 (four years) at Nepal Medical College and Teaching Hospital. The Type of variation was categorized according to Michel's classification. The values were further grouped under male and female categories. Data obtained was compiled and analyzed using SPSS 16. Out of 504 patients, 258 were males (51.2%) and 246 were females (48.8%). Youngest was nine years and the eldest was 93 years old with mean age of 48.1 years. The commonest variation was Michel's Type 1, seen in 371 (73.6%) followed by Type 2 in 61 patients (12.1%) and Type 3 in 46 (9.1%). Type 4 was seen in 11 patients (2.2%) and Type 5 variant in nine patients (1.8%). Only one patient each had Type 6 and 7 (0.2 % each). Two had Type 9 (0.4%). We did not find Type 8 and 10. Statistically significant difference between male and female was found only in Type 2 with females having higher prevalence. Two patients showed celiac trunk and SMA arising from single celiomesenteric trunk of abdominal aorta, accounting for 0.4% of total cases which was tabled under unclassified category. MDCT is excellent modality to depict normal and variant hepatic arterial anatomy. Michel's Type 1 is the commonest hepatic arterial anatomy variant and should be considered as normal "classic" pattern.

KEYWORDS

Hepatic artery variant, Michel's Type, MDCT angiography

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INTRODUCTION

In the modern era of hepatic surgeries like liver transplantation, partial resection, lobectomy, infusion therapy, and transarterial chemoembolization of neoplasm in the liver, it is mandatory to preoperatively identify the hepatic artery anatomy and its variants to minimize the complications during and after surgery. Multidetector Computed Tomography (MDCT) is the modality of choice for preoperative assessment of hepatic artery variations with an accuracy of 95-100%.[1] Moreover; it is a noninvasive technique with high sensitivity and specificity.

Although, the gold standard procedure for evaluating vascular structures is digital subtraction angiography (DSA), due to its invasive nature it has a limited role. At present, MDCT is used in place of DSA for the evaluation of vascular structures due to its less invasive nature and excellent image quality.[2]

The celiac trunk (CT) is the first anterior branch of the abdominal aorta (AA) and it arises from the AA immediately below the aortic hiatus at the level of the T12-L1 vertebra and measures about 1.5cm to 2cm in length. Its normal classic pattern is related to the origin of three branches, namely, the left gastric artery (LGA), which runs along the lesser curvature of the stomach and connects to the lower esophagus; the splenic artery (SA), which tortuously runs to the spleen, which supports the immune system by producing antibodies; and the common hepatic artery (CHA) supplies blood to the liver, duodenum, pancreas, and part of the stomach, which branches into the gastroduodenal artery (GDA), in the vascularization of the pancreas and duodenum, and the proper hepatic artery (PHA) which supplies the liver.[3] The division of the PHA into right (RHA), middle (MHA) and left hepatic arteries (LHA) occurs proximally to the liver within the hepatoduodenal ligament. Superior mesenteric artery (SMA) originates 1cm below the CT, at the level of the L1-L2 intervertebral disc.

Variations in AA and its branches are frequently observed and they occur due to embryological developmental changes. The arteries that show frequent variations include CT, renal & gonadal arteries. Ligation or damage of these arteries without knowing the possible variations in laparotomy, nephrectomy, renal transplantation, arterial reconstruction, laparoscopy, or other surgical applications may cause unpredictable complications, such as segmental or total visceral ischemia and failure. Hence, thorough knowledge of vascular anatomy with variants is vital to radiologists and surgeon.[4] The extrahepatic arteries must be identified with precision at the time of liver harvest to avoid injuries that might compromise complete artery ligation of the graft.[5] Vascular variations can also become a technical problem for infusion therapy and transarterial chemoembolization of neoplasm in the liver.[6-9]

In context of Nepal, study of hepatic arterial anatomy and its variation, using MDCT has not been published yet. This study aims at establishing prevalence of hepatic artery anatomical variations on MDCT in Nepalese population and evaluates its pre and post-surgical implications. Hence, this study aimed to calculate and tabulate the prevalence of Michel's Type 1 hepatic artery anatomy, identify other hepatic artery variants not classified under Michel's classification and assess prevalence of hepatic artery variant anatomy based on gender in the Nepalese population using 64-slice MDCT angiography.

MATERIALS AND METHODS

Cross-sectional descriptive study was conducted on 504 patients who underwent CT abdomen and pelvis with angiography between November 2018 and October 2022 (four years) at the Department of Radiology, Nepal Medical College and Teaching Hospital (NMCTH), Attarkhel, Gokarneshwor Municipality-08, Kathmandu. Patients with previous abdominal, abdominal vascular surgeries or obvious vascular anomalies like aneurysm or stenosis were excluded from the study.

All scans were performed using on Toshiba, Aquilon 64 slice CT machine. Images were evaluated on axial, coronal, sagittal, curved planar reformation and 3D volume-rendered reconstruction on Vitrea 2 console (Vital Images, Inc.; MediMarkW, Europe) by two radiologists with minimum of five years of experience each. The type of variation was categorized according to Michel's classification. The values were further grouped under male and female categories. General information of the patient like age, sex and hospital number was obtained from CT register. Data obtained was compiled and analyzed using Statistical Package of Social Services – 16 (SPSS-16). Descriptive analysis was presented in numbers and percentages and analytical statistics done using chi-square test.

RESULTS

A total of 504 patients enrolled in the study 258 were males (51.2%) and 246 were females (48.8%) as shown in Fig. 1. Youngest was nine years and the eldest was 93 years old with mean age of 48.1 years.

The commonest variation was Michel's Type 1, seen in 371 (73.6%) out of 504 patients (Table 1 and Fig. 2). Out of 258 males, 203 (78.8%) and out of 246 females, 168 (68.1%) had Michel's Type 1 variant (Fig. 2). The second most common variant was Michel's Type 2, seen in 61 patients (12.1 %) out of which 19 were males (7.1 % of total 258 male patients) and 42 were females (17.1% of total 246 female patients) (Fig. 3).

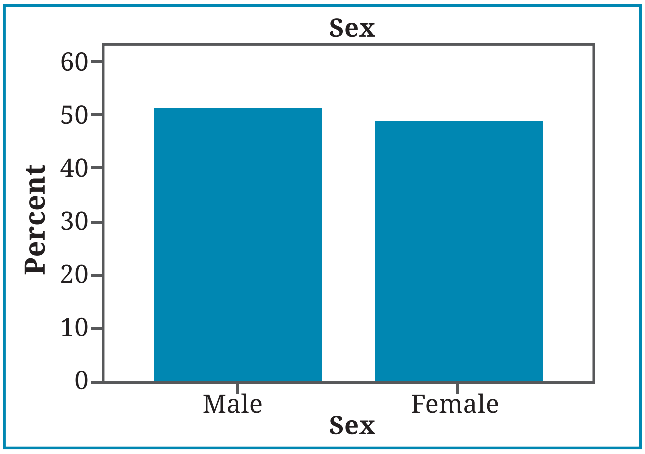

Fig. 1: Case distribution according to gender

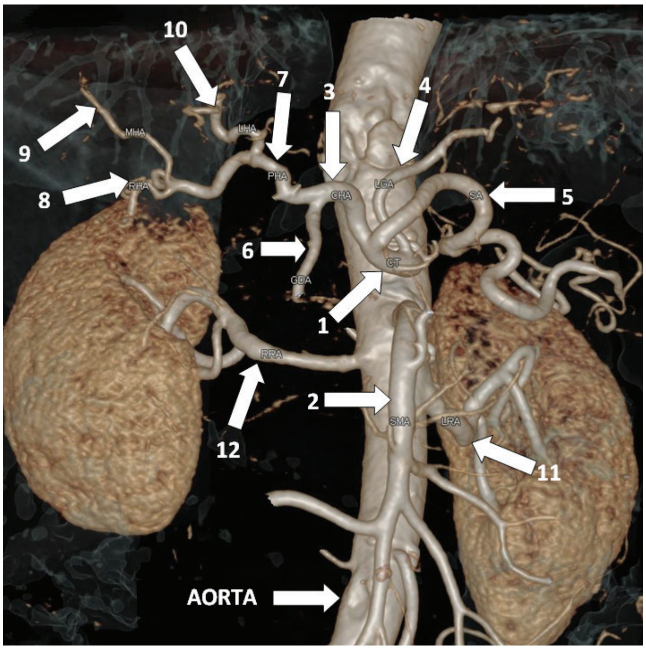

Fig. 2: 3D volume rendered CT image of Michel's Type 1 hepatic arterial anatomy. *1 = CT, 2 = SMA, 3 = CHA, 4 = LGA, 5= SA, 6 = GDA, 7 = PHA, 8 = RHA, 9 = MHA, 10 = LHA, 11 = left renal artery, 12 = right renal artery.*

Table 1: Frequency of prevalence of Michel's Type

Michel's Type	Number of patients	%
1	371	73.6
2	61	12.1
3	46	9.1
4	11	2.2
5	9	1.8
6	1	0.2
7	1	0.2
8	0	0.0
9	2	0.4
10	0	0.0
Unclassified	2	0.4
Total	**504**	**100.0**

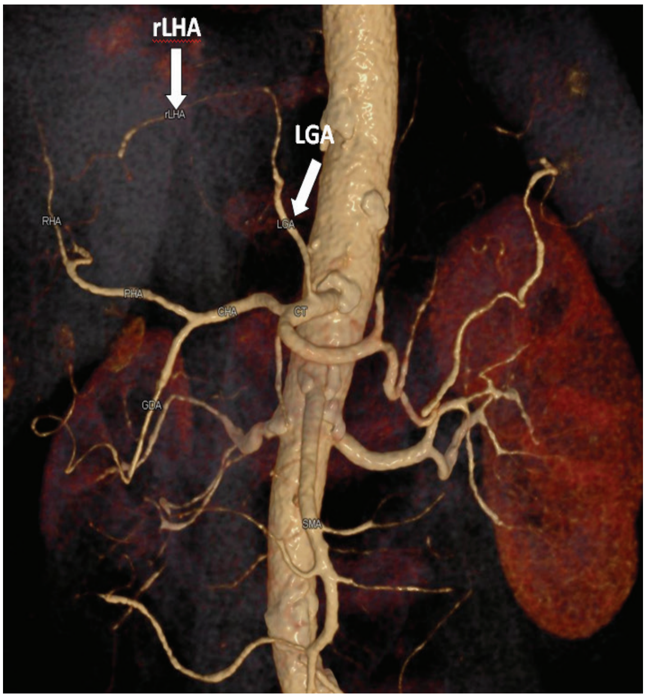

Fig. 3: 3D volume rendered CT image of Michel's Type 2 hepatic arterial anatomy. *rLHA = replaced left hepatic artery arising from left gastric artery (LGA)*

Similarly, the third most common was Michel's Type 3 seen in 46 (9.1%) patients with males being 26 (10.0%) and females 20 (8.1%) (Fig. 4). Michel's Type 4 variant was seen in 11 patients (2.2%) amongst which males were six (2.1 %) and females five (2.0%) (Fig. 5). Likewise, Michel's Type 5 variant was seen in nine patients (1.8%) with males numbering two (0.7%) and females seven (2.8%) (Fig. 6). Only one female patient each had Michel's Type 6 and 7 variants (0.2% of total and 0.4% of female patients) and no male had these variants (Fig. 7 and 8). Two females had Michel's type 9 variant which is

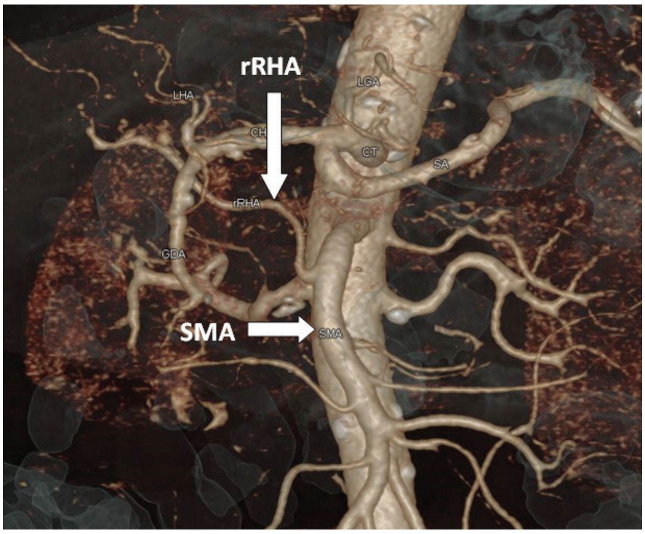

Fig. 4: 3D volume rendered CT image of Michel's Type 3 hepatic arterial anatomy. *rRHA = replaced right hepatic artery arising from superior mesenteric artery (SMA)*

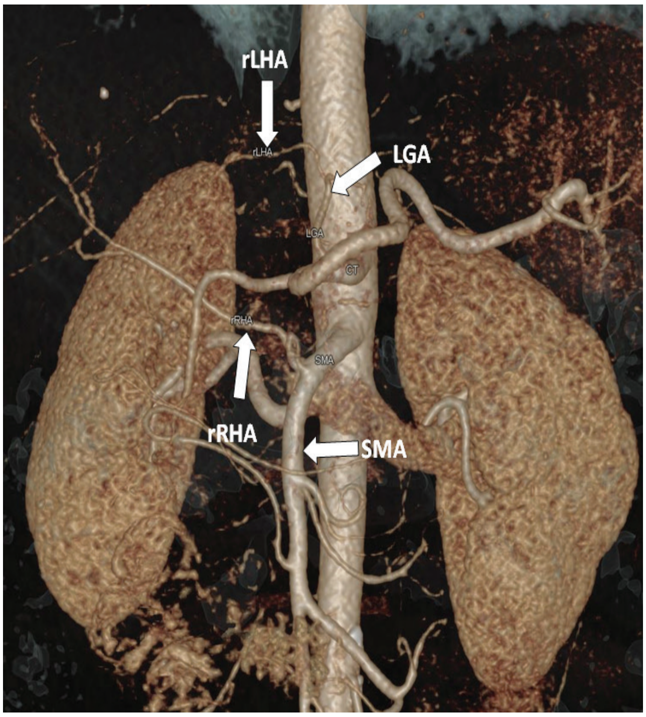

Fig. 5: 3D volume rendered CT image of Michel's Type 4 hepatic arterial anatomy . *rLHA arising from LGA and rRHA from SMA*

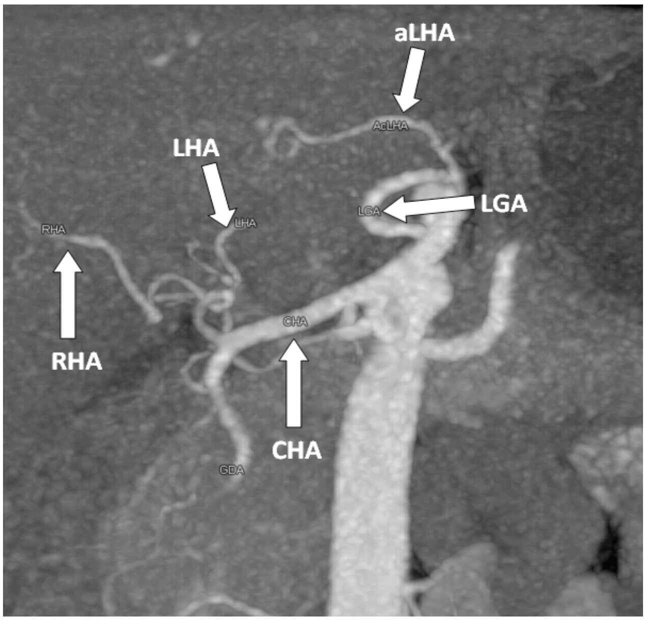

Fig. 6: Coronal maximum intensity projection (MIP) CT image of Michel's Type 5 hepatic arterial anatomy.*aLHA = accessory left hepatic artery arising from LGA*

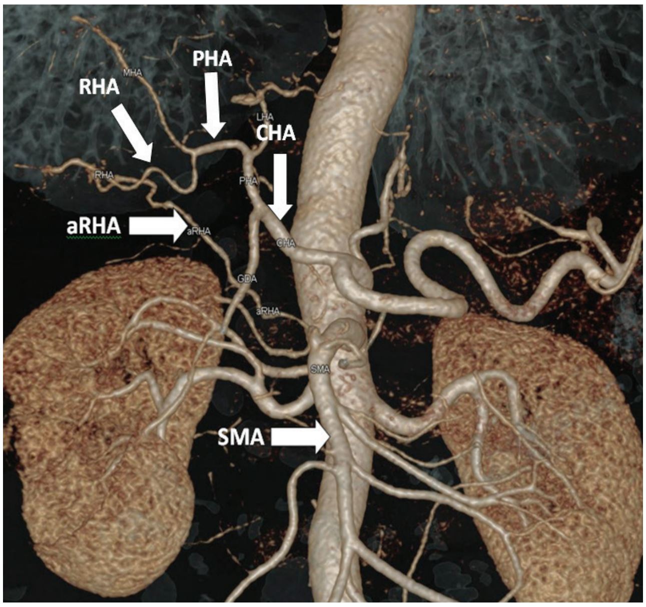

Fig. 7: 3D volume rendered CT image of Michel's Type 6 hepatic arterial anatomy. *aRHA = accessory right hepatic artery arising from SMA and main RHA arising from PHA*

Table 2: Distribution of frequency of Michel's Type according to gender

Sex	Michel's Type											Total
	1	2	3	4	5	6	7	8	9	10	Unclassified	
Male	203 (78.8%)	19 (7.1%)	26 (10.0%)	6 (2.1%)	2 (0.7%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (0.7)	258
Female	168 (68.1%)	42 (17.1%)	20 (8.1%)	5 (2.0%)	7 (2.8%)	1 (0.4%)	1 (0.4%)	0 (0.0%)	2 (0.8%)	0 (0.0%)	0 (0.0%)	246
Total	**371**	**61**	**46**	**11**	**9**	**1**	**1**	**0**	**2**	**0**	**2**	**504**

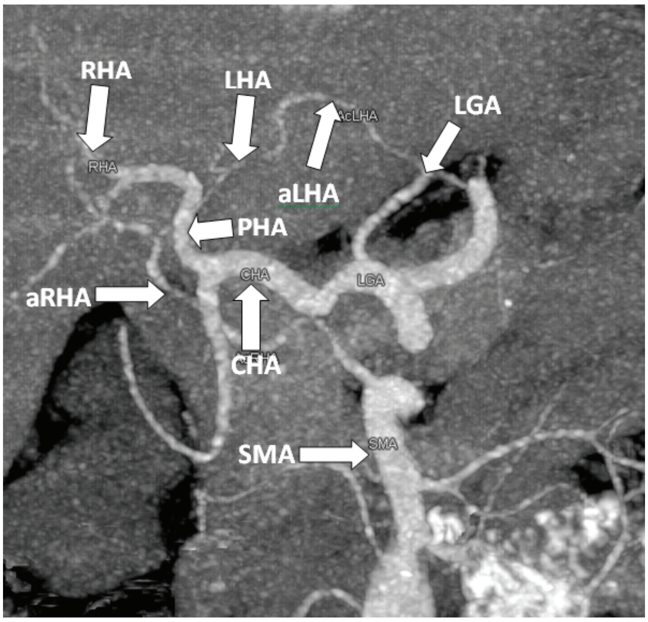

Fig. 8: Coronal MIP CT image of Michel's Type 7 hepatic arterial anatomy. *aLHA arising from LGA and aRHA from SMA. Main RHA and LHA as branches of PHA*

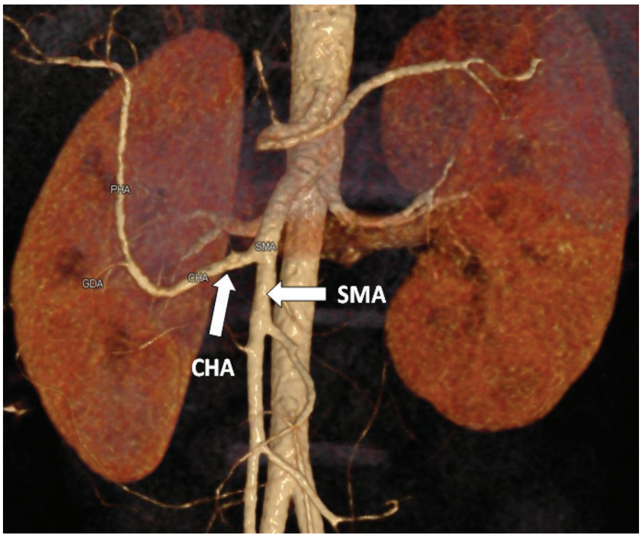

Fig 9: 3D volume rendered CT image of Michel's Type 9 hepatic arterial anatomy. *Common hepatic artery (CHA) arising from SMA*

0.4% of total and 0.8% of female patients (Fig. 9 and Table 2). We did not find Michel's type 8 and 10 variants.

Statistically significant difference between male and female was found only in type 2 using chi- squared test with post hoc analysis (p value <0.005) with higher prevalence of type 2 in females. Statistically significant differences between the two genders were not seen in other Michel's variants. Two male patients had common origin of celiac trunk and SMA

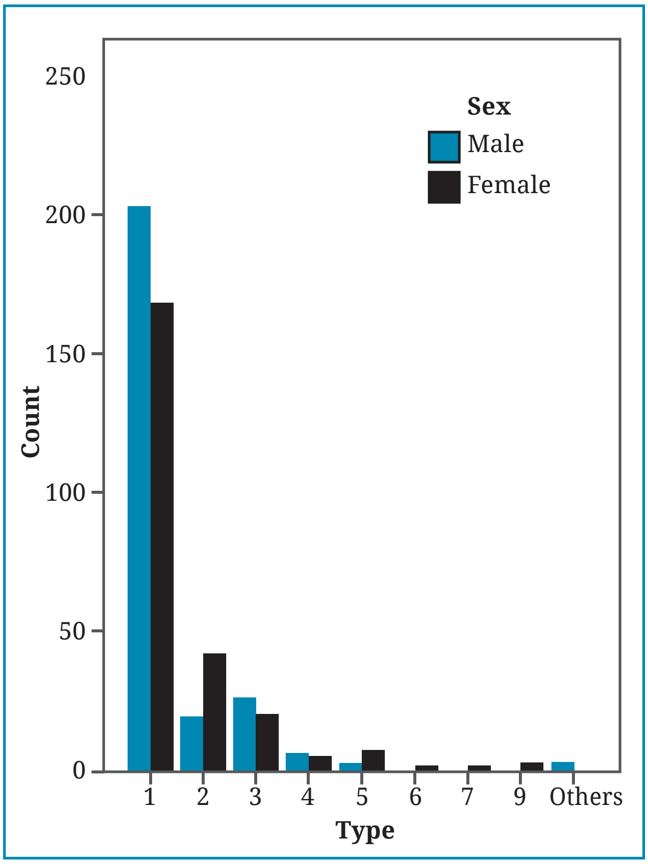

Fig. 10: Bar diagram of frequency of Michel's Type according to gender

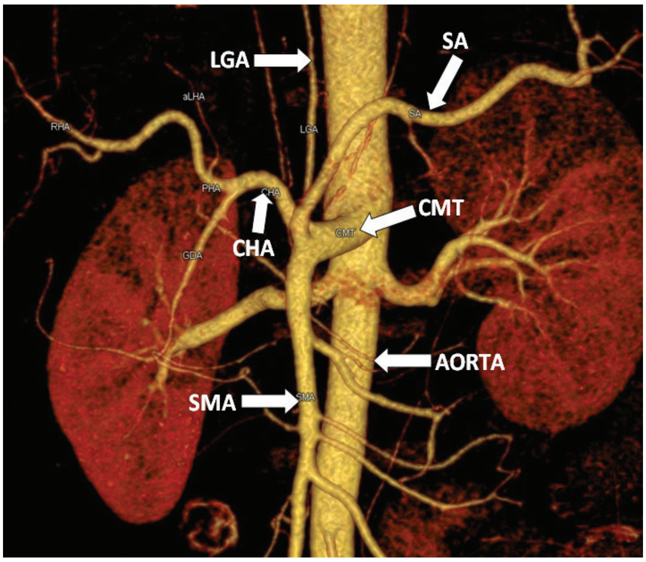

Fig 11: 3D volume rendered CT image of *celiomesenteric trunk (CMT) arising from abdominal aorta and giving rise to SMA, CHA, splenic artery (SA) and LGA. This variant is not described in Michel's classification but is categorized as Type 6 under Uflacker's classification*

arising from single celiomesenteric trunk from abdominal aorta, accounting for 0.4 % of total cases (Fig. 11). This anatomical variant was tabled under unclassified category.

Table 3: Michel's and Hiatt's classifications of hepatic arterial anatomy.		
Michel's classification	**Hiatt's classification**	**Hepatic artery variations**
Type 1	Type 1	Normal anatomy (classical trifurcation)
Type 2	Type 2	The replaced LHA originating from the SMA
Type 3	Type 3	The replaced RHA originating from the SMA
Type 4	Type 4	Co-existence of Types II and III
Type 5	Type 2	The accessory LHA originating from LGA
Type 6	Type 3	The accessory RHA originating from SMA
Type 7	Type 4	The accessory LHA originating from LGA + the accessory RHA originating from SMA
Type 8	Type 4	The accessory LHA originating from LGA + the replaced RHA originating from SMA
Type 9	Type 5	The CHA originating from SMA
Type 10	NOD	RHA and LHA originating from the LGA
NOD	Type 4	The CHA directly originating from the aorta

CHA- common hepatic artery; LGA- left hepatic artery; NOD- not otherwise described in the literature; RHA- right hepatic artery; SMA- superior mesenteric artery

Table 4: Uflacker's classification of celiac trunk variants	
Type	**Description**
Type 1= trifurcation	
Classic pattern:	The CHA, SA and LGA have a common point of origin from the celiac trunk
Non classic pattern:	CHA and SA have a common point of origin with the LGA demonstrates a variable points of origin
Type 2= hepato-splenic trunk	CHA and SA have common trunk with the LGA arises separately from aorta
Type 3= hepato-gastric trunk	CHA and LGA have common trunk with the SA arises separately from the aorta or SMA
Type 4= hepato-spleno-mesenteric trunk	CHA, SA and SMA have common trunk with the LGA arises separately from the aorta
Type 5 = gastro-splenic trunk	LGA and SA have a common trunk with the CHA arises separately from the aorta or SMA
Type 6= celiaco-mesenteric trunk	Celiac and SMA have a common trunk
Type 7= celiaco-colic trunk	The middle colic artery and the celiac have the same trunk
Type 8= no celiac trunk	No celiac trunk with the CHA, SA and LGA arises directly from the aorta

DISCUSSION

In 1966, Michels[10] described his classification scheme for anatomic variations in the hepatic arterial blood supply based on the results of dissecting 200 cadavers (Fig. 12). It defined the 10 basic anatomic variations in hepatic arterial supply that have served as the benchmark for all subsequent contributions in this area. In 1971, Suzuki *et al*[11] contributed an article on the surgical importance of anatomic variants of the hepatic arteries that were based on findings in 200 patients examined with cutfilm angiography. It emphasized the detailed hepatic arterial variation at the hepatic hilum. This classification was modified to 6 types by Hiatt[6]

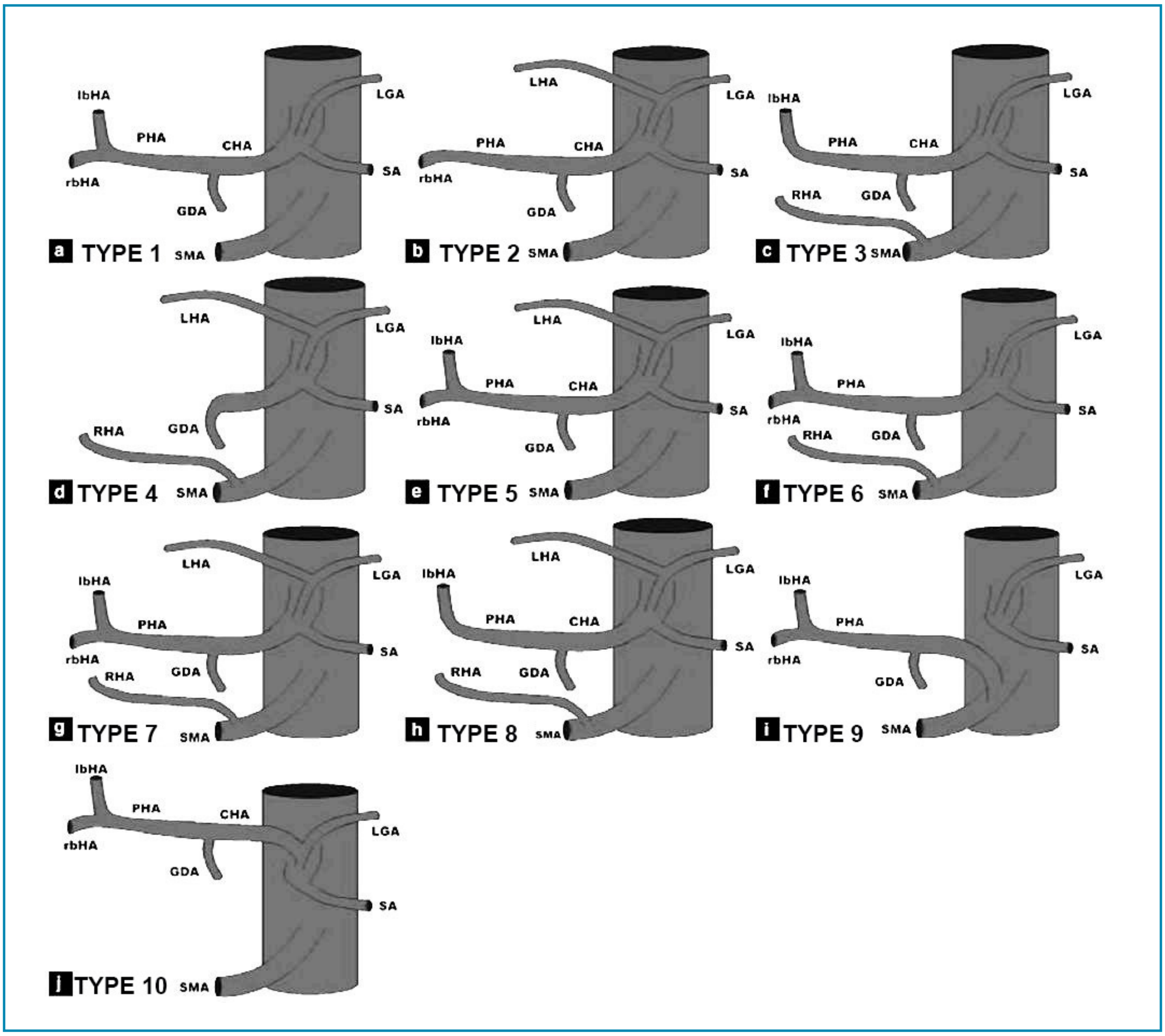

Fig. 12: Variants of hepatic artery according to Michel classification. rbHA – right branch of hepatic artery; lbHA- left branch of hepatic artery

Table 5: Comparison of frequency percentages of hepatic arterial anatomy variation between this study and other classifications

Type	Current study (N=504) %	Michel classification (N=200) %	Hiatt's classification (N=1000) %
1	73.6	55.0	75.7
2	12.1	10.0	9.7
3	9.1	11.0	10.6
4	2.2	1.0	2.3
5	1.8	8.0	1.5
6	0.2	7.0	0.2
7	0.2	1.0	
8	0	4.0	
9	0.4	4.5	
10	0	0.5	
Unclassified	0.4	0	

in 1994 which included three angiographic studies and one study on transplantation grafts. Although Michel's and Hiatt Type 1, 2 and 3 are the same, there are differences in other types (Table 3). Hiatt Type 4 is coexistence of Michel's Type 2 and 3, Michel's type 5 is Hiatt's Type 2, Michel's Type 6 is Hiatt's type 3 , both Michel's Type 7 and 8 is Hiatt's Type 4, Michel's Type 9 is Hiatt's Type 5 , Michel's type 10 is not described in Hiatt's classification and Hiatt's Type 6 is not described in Michel's classification.

Uflacker's classification on the other hand describes the variation in celiac trunk branching pattern and has been frequently used in large cross sectional studies comparing the prevalence of this classification with Michel's (Table 4). A study on 1285 Egyptian patients using MDCT found Michel's Type 1 in 742 (74.2 %) and celiacomesenteric trunk (Uflacker's Type 6) in 6 (0.6%) patients of total cases.[12] This is comparable to our study where Michel's Type 1 was found in 73.6% and celiacomesenteric trunk (Ufalcker's Type 6 which was categorized as unclassified in our study) was found in 0.4 % of the patients (Fig. 10 and 11). No celiac trunk was found in 10 (1%) of the patient in the Egyptian study, where as we found no patient with absent celiac trunk.

Not all hepatic vascular anomalies are surgically significant. The level of importance varies depending on whether the variants appear in the donor or the recipient. Some of the variants are significant for the donor whereas some variations are important for the recipient and some for both.[13,14]

An important hepatic arterial variant is the supply to segment IV from the right hepatic artery which affects a donor who requires a full arterial supply to the left lobe of the liver. Although Kostelic *et al*[15] believe that 50% of the anomalous hepatic arterial configurations are technically incompatible or have potentially adverse effects on the outcome of the surgery.

In the study by Matusz *et al*[16] the trifurcation is reported in the literature as occurring in 89% of the cases, while bifurcation occurs in 11%. Absence of this trunk occurs in 0.2% of the individuals. According to Ugurel *et al*[17] in a retrospective study of 100 CT images, there was a celiac trunk trifurcation in 89% and bifurcation in 8% of the cases. Coeliac trunk was absent in 1%. The hepatic arteries had a normal anatomy (Type 1) in 52% of patients. The most common hepatic artery variations were replaced right hepatic artery (Type 3) (17%), replaced left hepatic artery (Type 2) (11%) and accessory left hepatic artery (Type 5) (10%) according to Michel's classification. On the basis of Hiatt's classification, on the other hand, the most common hepatic artery variation was accessory or replaced left hepatic artery (Type 2) (22%). Three of the 100 patients had unclassified hepatic artery variations. One of these was a right hepatic artery that originated from the middle colic artery, one was a right hepatic artery that originated directly from the aorta; and the third was a left hepatic artery originating from the common hepatic artery. Liver segment IV arteries, originating from the RHA, were determined in 35 of the 100 cases. Our study findings were comparable to these two studies if we considered all Michel's Types to trifurcate apart from Michel Type 9 which show bifurcation of celiac trunk (99.6% and 0.4% respectively). However, in our study Michel's Type 2 was second most common rather than Type 3 followed by Type 3, 4 and 5. We did not come across RHA arising from middle colic artery or directly from aorta or absent celiac trunk in our study. Segment IV arteries arising from RHA were not evaluated in this study as we only looked for branching pattern of CHA and not distal branches beyond main hepatic arteries.

Covey *et al*[18] studied hepatic artery variation in 600 subjects. Three hundred sixty-eight (61.3%) patients had the standard hepatic arterial anatomy and the rest two hundred thirty two (38.7%) had other variant anatomy. One hundred nineteen (19.8%) patients had variant left hepatic arteries (LHAs), and 89 (14.8%) had variant right hepatic arteries (RHAs). Twenty-eight (4.7%) patients had a variant anatomy involving both the LHA and the RHA. Twenty-four (4.0%) patients had a variant origin of the common hepatic artery (CHA) arising from either the superior mesenteric artery (SMA) or the aorta. In two patients, the proper hepatic artery (PHA) was the first branch of the SMA and the gastroduodenal artery (GDA) was a branch of the celiac axis. Double hepatic arteries were seen in 22 (3.7%) patients. Trifurcation or quadrifurcation of the GDA was seen in 50 (8.3%) patients, and the GDA originated distal to one hepatic artery in 25 (4.2%) patients in whom both hepatic arteries originated from the CHA. Our study showed slightly higher prevalence of Michel's Type 1 (73.6%) compared to Covey *et al*[18] and rest 26.4% had other variants.

Retrospective study by Choi *et al*[19] included 5625 patients who underwent liver CT and chemoembolization showed the prevalence of accessory RHAs (15.63%) and the prevalence of accessory LHAs (16.32 %) were similar. Accessory hepatic arteries were seen in only 11 patients (2.2 %) in our study, out of which nine patients had accessory LHA, one had accessory RHA and another had both right and left accessory hepatic arteries.

In a study of 479 liver transplantation patients by Lucena *et al*,[20] normal hepatic arterial anatomy was identified in 416 donors (86.84%). The other 63 patients (13.15%) showed other variations including like Type 3 in 5.63% , Type 2 in 2.71% and Type 4 in 0.83% . Fourteen donors (2.92%) showed no anatomical abnormalities defined in classifications, the highest frequency being celiomesenteric trunk identified in five (1.04%). Prevalence of normal hepatic arterial anatomy (Michel's Type 1) was lower (73.6%) and that of Type 2 (12.1%), 3 (9.1%) and 4 (2.2 %) were higher in our study compared to that by Lucena *et al*.[20] Presence of celiomesenteric trunk was identified in two (0.4%) of our patients which is comparable to 1.04% found in aforementioned study.

A systemic review of literature on total of 19,013 patients by Noussios *et al*[21] revealed that 81% displayed normal anatomy (Michel's Type 1) , 3.7% showed type 3 , 3% had Type 2 , 0.8% had Type 4, while 3.2% and 1.6% had type 5 and 6 respectively. Type 9 appeared in 1.2% of cases. Again, compared to this study our study showed lower prevalence of Michel's Type 1, 5, 6 and 9 but higher that of other variants.

Since both Michel's and Hiatt's Type 1, 2 and 3 describe the same variants; we could only compare these three variants with our study. Compared to Michel's classification, only Type 1 had lower higher prevalence in our study. Type 2 and 3 had similar frequencies compared to both Michel's and Hiatt's classifications (Table 5).

Another interesting observation made was both male patients with celiomesenteric trunk (unclassified category in our study) showed accessory LHA arising from PHA and replaced LHA arising from LGA which has not been reported and classified in literature yet.

Such a wide diversity of data extracted from different populations leads to the questioning of the universal and indiscriminate applicability of only one reference source, particularly when populations with different ethnicities are considered.[22]

Hence, although, sufficient number of patients was attempted to be included in this study, larger population sample size is required to more clearly depict the prevalence of hepatic artery variants in Nepalese population.

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