Variations of Extrahepatic Segments of Hepatic Arteries: A Multislice Computed Angiography Study

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Abstract - Hepatic artery variations are important to the surgeons performing procedures in and around the porta hepatis in order to avoid injury to vascular and ductal structures. This cross sectional study was carried out in the Departments of Anatomy and Radiodiagnosis, KGMU, U.P, Lucknow, India. CT-angiograms of 50 subjects were analyzed. Various patterns of hepatic arterial anatomy were observed in the study. These included, normal anatomical origin of CHA from the celiac trunk in 95.92% with CHA displaying a variant anatomical relationship in 2.04% cases. Anomalous origin of CHA from the aorta was found in 4.08% cases. Replaced RHA was found in 16% whereas accessory RHA was found in 14% cases. Observations of LHA anatomy displayed replaced origin from CHA and LGA whereas accessory LHA could be traced to the LGA. Variant arteries displayed an anomalous course.

Index Terms: Hepatic artery, Aberrant hepatic artery, Celiac trunk, CT-Angiogram, Liver transplantation

I. Introduction

This epatic arterial anatomy represents one of the many "lessons for the general surgeon" that have emerged from the development of liver transplantation. Pre-operative arterial imaging is of paramount importance to plan open and endovascular procedures involving the upper abdominal organs due to the recent advancements in surgical and interventional options for patients with primary and metastatic liver tumors. Preprocedural CT evaluation of the celiac axis and hepatic artery anatomy can help one perform and interpret the findings of diagnostic angiography for intra-arterial management of hepatic tumors and perform embolotherapy for hemorrhage [11, 14]. Variations in these vessels may predispose patients to inadvertent injury during open surgical procedures or percutaneous interventions. The introduction of laparoscopic cholecystectomy has stimulated a renewed interest in anatomy of the hepatic arteries and bile ducts. The variant patterns of the major vessels are also relevant because they will affect the laparoscopic appearance of the porta hepatis.

The hepatic artery "normally" originates from the celiac trunk and branches close to the porta hepatis into the left hepatic artery (LHA) and right hepatic artery (RHA). The artery may be subdivided into the common hepatic artery (CHA) - from the celiac trunk to the origin of the gastroduodenal artery and the hepatic artery 'proper' (PHA) from that point to its bifurcation [25]. It ascends in the free border of the lesser omentum and at the porta hepatis divides into right and left branches. This normal anatomy is observed in 55%-80% of population [6, 13, 19]. Modifications of the dominant scheme occur.

The normal and variant anatomy of the hepatic artery has been described adequately in the literature [17, 18, 21, 22]. In 1969, Vandamme et al published their experiences with 156 postmortem angiograms that were obtained before anatomic dissection. Since then major technical advances in angiography have occurred. Thin-section dynamic CT has replaced conventional angiography for preoperative imaging evaluation of the hepatic vasculature [12, 28].

The purpose of our study was to evaluate and describe the prevalence of the hepatic arterial variants observed in north Indian population with the use of Multidimensional CT (MDCT). This knowledge may be helpful in accurate interpretation of disease, in diagnostic imaging, as well as in deciding the optimum elective procedure in surgical or interventional radiological management. It may also open the way for thinking about some potential explanations for certain clinical entities based on these anatomical variations.

II. MATERIALS AND METHODS

In the present study 50 subjects including both males and females (age group between 18 months to 78 years) were examined by by *Multislice CT Angiography*. CT Angiography was performed on a multislice spiral CT scanner. This cross sectional study was carried out after approval by our institutional ethical review board. The study was conducted in Departments of Anatomy and Radiodiagnosis, KGMU, Lucknow (U.P), India.

All persons male or female of all ages undergoing abdominal CT for any indication were included in the study. Patient consent was taken. We excluded patients suffering from aorto arteritis, collagen vascular disorder, with history of previous abdominal surgery, abdominal malignancy distorting the vascular anatomy and any known disorder that could affect the region of study.

Criteria for identification of vessels on CTA-

- CHA- an arterial trunk containing at least one segmental hepatic artery and the gastroduodenal artery, irrespective of its origin site and anatomic course.

- PHA - an arterial trunk before branching into the right and left hepatic arteries, regardless of its origin site or anatomic course.
- LHA & RHA – the arteries supplying the right and left liver substance.

The dynamic spiral CT scans were obtained. MDCT raw data was transferred to a computer workstation and processed using multiplanar reformation (MPR) technique, maximum intensity projection (MIP), curved planar reconstruction, and volume rendering (VR). The anatomical variations detected on 3-D images were studied on the axial source images. Multiplanar reconstructions (MPRs) were used to study the anatomical relationship to the surrounding structures. The axial images were used for final confirmation of variant anatomical findings.

III. RESULTS

1. Variations of common hepatic artery

In 95.92% cases CHA displayed a normal anatomical origin from the celiac artery or its equivalent (Fig.1). In 4.08% CHA originated from the aorta (Fig.2). We observed a single case of absent CHA. In this particular case LHA originated from LGA, the RHA originated from the SMA and the GDA was seen arising from the aorta (Fig.3) (Table 1).

Common hepatic artery coursed superior to the pancreas (suprapancreatic) in all the subjects where it was present (28 males, 21 females). In majority of cases (97.96%) CHA was present ***anterior*** to the portal vein (Fig.4a). In 2.04% cases CHA coursed ***posterior*** to the portal vein (Fig.4b).

2. Variations of right hepatic artery

In 86% cases a single right hepatic artery was found, whereas, in 14% cases two right hepatic arteries were found. Within the single artery group in 83.72% cases RHA originated from the PHA (Fig.5). Variant origins of the RHA were observed from SMA in 11.62% (Fig. 6), CA (2.33%) (Fig. 7) and the GDA in 2.33% subjects (Fig.8). **Accessory** right hepatic arteries were observed in 14% cases. In 6% cases the accessory RHA originated from the celiac trunk whereas in 8% cases the accessory artery was given off as a branch of the SMA (Table 2).

Out of 43 cases with single RHA, a ***preportal*** RHA coursing anterior to the portal vein was observed in 90.70% (n=39) cases whereas a variant ***retroportal*** course of the single RHA behind the portal vein was observed in 9.30% (n=4) cases .

Single RHAs passing posterior to the common hepatic duct (normal anatomical description) were seen in 81.40% (n=35) cases whereas variant course of the single RHA where it was anterior to the common hepatic duct was seen in 18.60% (n=8) cases.

Accessory RHAs traversed posterior to the portal vein (through the portocaval space), and posterior to the common hepatic duct irrespective of their site of origin all the 7 cases (Fig.9) (Table 3).

3. Variations of the left hepatic artery

Single left hepatic artery (LHA) was found in 96% (n=48) cases of the total. Amongst these cases LHA originated from the PHA in 83.33% (Fig.10). Origin of the LHA could also be traced to the CHA in 12.50% (Fig.11) and from the LGA in 4.17% cases (Fig. 12). Accessory LHAs were seen in 4% (n=2) cases. In both the cases accessory LHAs were branches of LGA (Table 4).

The RHA displayed *significantly higher* prevalence of variations as compared to the LHA. 2% (n=1) cases had a variant anatomy involving both the RHA and LHA.

IV. DISCUSSION

In upper abdominal surgery, hepatic arterial blood flow should be preserved whenever possible to avoid or minimize serious hepatic ischemic complications.

CHA is the key component of the variant anatomy in describing variations for image interpretation, communication with surgeons, and scientific communication. The CHA can have a variant origin other than the celiac axis and take various anatomic courses [5, 34]. The specific type of celiac axis or hepatic artery variation can be appropriately named according to the definition of the CHA, and more complex combined variations could thus be objectively described as stated by Song *et al*., 2010.

CHA was absent in 2% cases in our study whereas Song *et al*. reported absent CHA in 1.1%. We found CHA origin from the celiac axis or its equivalent in 94% cases out of which 2% CHAs had variant relationship to the pancreas and portal vein whereas Song *et al*., reported a lower prevalence of variant CHA originating from the celiac axis in 0.15%. The variant CHAs passed through the retroportal space a course identical to that of a variant right hepatic artery arising from the CHA or the celiac axis [7, 20]. CTA studies have reported replaced CHA origin from aorta in 0.40%, but we reported a higher prevalence of variant CHAs (4%) originating from aorta. All variant CHAs had a normal suprapancreatic preportal course in accordance with the study of song et al. Variant CHA has been most commonly reported from SMA [26, 32]. We could not find any variant CHA originating from the SMA in our study probably due to a smaller sample size.

The aberrant hepatic arteries may be *incidental/ accessory* or *replaced artery* .Variations in the hepatic arterial pattern which have been reported in the literature are purely based on the origin of the hepatic artery and its branching pattern. We found replaced RHAs in 14% which included a variant origin from SMA in 7% lower than a previous study [4] which encountered replaced RHA arising from the SMA in 15% and another [3] which also reported that approximately 12.2% of individuals were found to have variant right hepatic arterial supplies. Another study has reported variant RHA from the SMA in 17% and from the GDA in 6% [8]. *Accessory* right hepatic arteries were observed in 14% (CA 6%, SMA 8%) cases whereas previous studies found accessory right hepatic arteries from SMA in 2.5% [3]. These accessory arteries originating from SMA traversed posterior to the portal vein (through the portocaval space), and posterior to the common hepatic duct. Accessory hepatic arteries have also been reported from GDA, LGA and right phrenic artery [3].

We observed replaced LHA from CHA in 12.50% and LGA in 4.17% but our findings differed from other studies which observed replaced LHA from LGA in 8% [32] and 17% [23] cases. Accessory LHAs were found originating from LGA in 4%

subjects in our study. This finding was in variance to another angiographic study which reported a prevalence of 15% [3] and a cadaveric study which found accessory left hepatic artery from the LGA in 8.8% [23].

Occurrence of aberrant vessels can be explained on embryological basis, according to which there should be presence of sufficient quantities of signalling molecules and growth factors produced by the developing and migrating mammalian cells for the normal development of any viscera. In the event of an improper signalling and incorrect gradient visceral anomalies may occur [10].

The anatomical knowledge of different variations of hepatic artery is required to reduce the number of iatrogenic complications in traditional and laparoscopic hepatobiliopancreatic surgery [24]. Likewise, the surgeon applies this knowledge in the surgical management of liver trauma in the region [15, 24], aneurysm of the hepatic artery, liver transplant surgery [1, 16] pancreaticoduodenectomy [22], radical gastrectomy [30] and countless surgeries themselves of this complex anatomical region. When the right hepatic artery originates from the superior mesenteric artery or directly from the aorta and courses in relation to the head of pancreas it can be injured during pancreaticoduodenectomy if it is not recognized. Therefore existence of such variants should be sought systematically by a careful dissection of the hepatic pedicle and the adventitial dissection of the superior mesenteric artery [9, 27].

During dissection of nodes in radical gastrectomy, surgeon should take into account the presence of aberrant left hepatic artery originating from left gastric artery, especially if replacement, a situation that would require the surgeon to perform a left hepatic lobectomy in case of injury [30]. During the laparoscopic treatment of gastroesophageal reflux, the presence of a left hepatic artery may pose difficulties during surgery. The clipping section of this artery can lead to hepatic necrosis. To expose the hiatal region in these cases wide dissection of the aberrant left hepatic artery should be carried out for its mobilization down [5].

In liver transplantation surgery, it is necessary to understand fully the anatomy and possible variations of irrigation liver donors. During orthotopic liver transplantation, the arterial reconstruction is an important step. The presence of an anatomical variation of the hepatic artery of the donor requires an adaptation of the arterial reconstruction technique to obtain an optimal perfusion of the territories of the graft and avoid certain complications which are dominated by thrombosis of the hepatic artery [2,16].When questions arise during bench surgical preparation of the graft, assistance of an angiogram can be helpful to better understand variant anatomy before further dissection is carried out.

Therefore knowledge about the diverse hepatic artery variations observed in our study may be helpful for planning surgical and/ or interventional procedures [31, 33].

Conclusion:

The anatomy of the hepatic artery is subject to many variations. These anatomical variations are the result of a complex organogenesis through intricate steps.

A higher prevalence (14%) of accessory right hepatic arteries was found in the present study. Variation of right hepatic artery was **significantly higher** (44%) than the left (20%). Accessory left hepatic artery was invariably arising from LGA.

These data are useful for the planning and conduct of radiological and surgical procedures.

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FIGURES

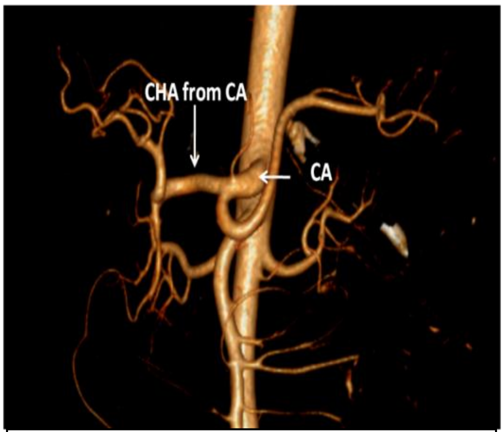

Figure:1 3D VR surface shaded display revealing normal anatomical origin of the common hepatic artery (CHA) from the celiac axis (CA).

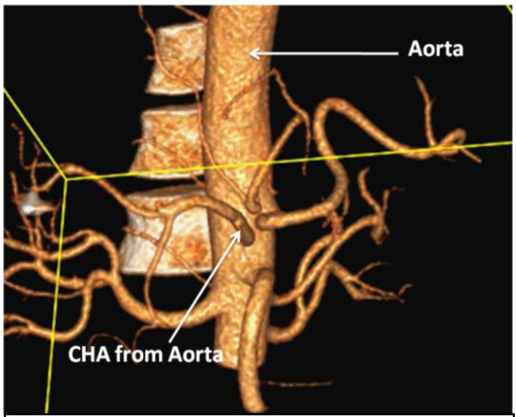

Figure:2 A three dimensional volume rendered (3D VR) image showing a variant origin of the common hepatic artery (CHA) directly from the aorta.

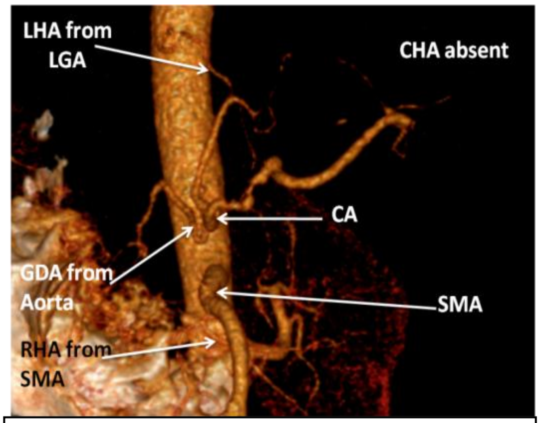

Figure:3 A 3D VR image showing absent common hepatic artery. LHA originates from LGA, RHA originates from SMA and GDA originates directly from the aorta.

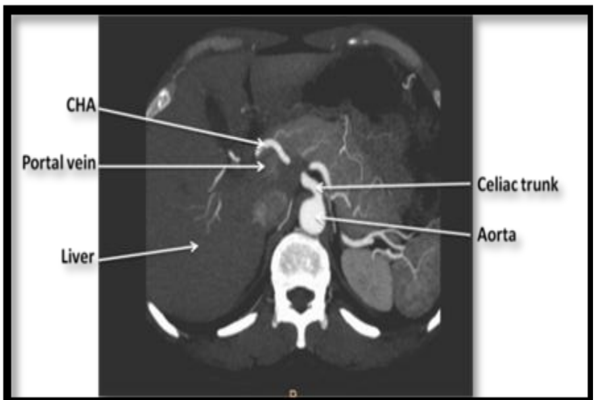

Figure:4a An Axial thick slab maximum intensity image showing CHA anterior to the portal vein.

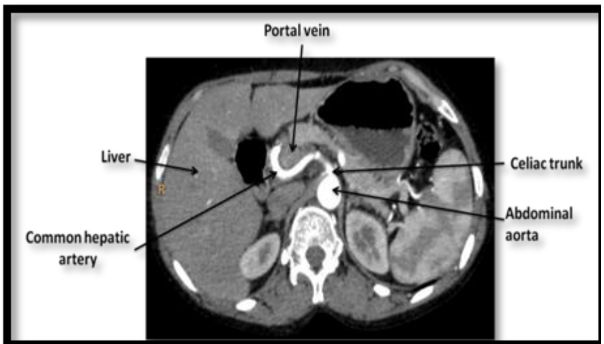

Figure:4b An Axial thick slab maximum intensity image showing CHA posterior to the portal vein.

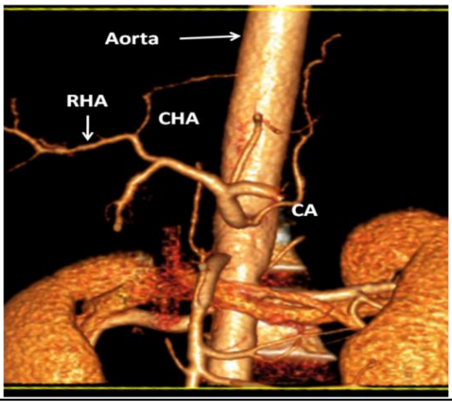

Figure:5 3D Volume rendered image showing RHA originating from the Proper hepatic artery.

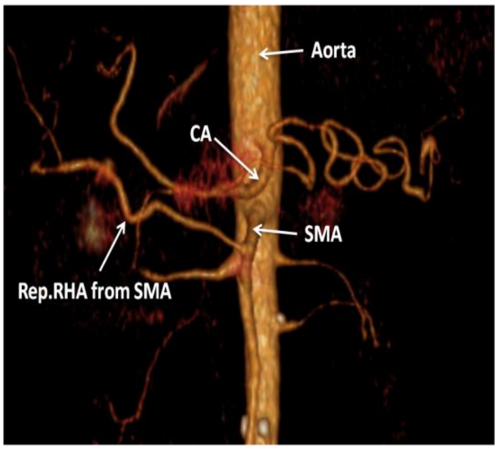

Figure:6 3D VR image showing replaced origin of the right hepatic artery (Rep. RHA) from SMA.

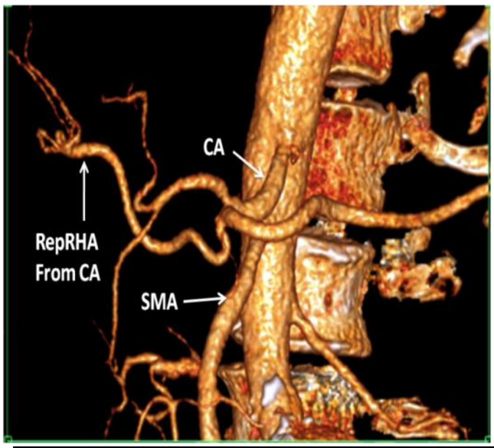

Figure:7 3D VR image showing replaced right hepatic artery(Rep.RHA) originating from the celiac axis (CA).

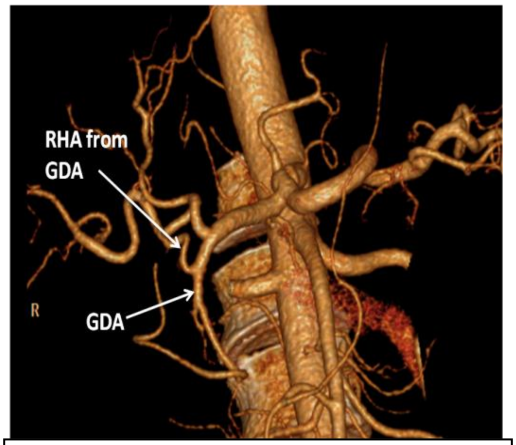

Figure: 8 3D VR image showing replaced right hepatic artery (Rep.RHA) taking origin from the gastro duodenal artery

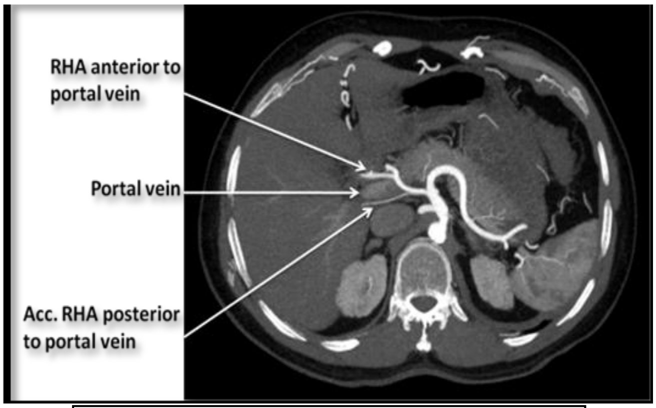

Figure: 9 Axial MIP image showing course of normal and accessory RHAs in relation to portal vein.

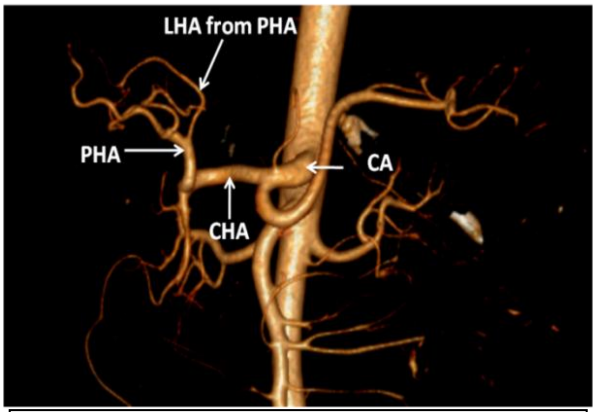

Figure: 10 3D VR reformatted image showing origin of the left hepatic artery (LHA) from the proper hepatic artery (PHA).

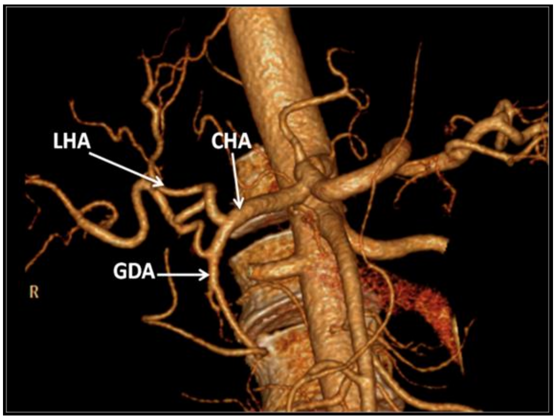

Figure: 11 3D VR reformatted image showing a variant origin of the left hepatic artery (LHA) from the common hepatic artery (CHA).

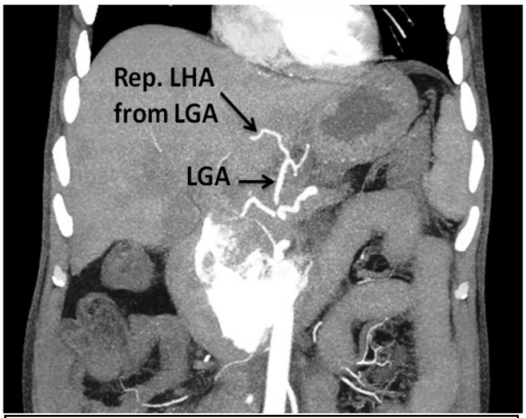

Fig.12 3D VR image showing replaced left hepatic artery (Rep.LHA) from the left gastric artery (LGA).

TABLES

TABLE -1

Prevalence of various sites of origin of the common hepatic artery according to gender

Name of the source vessel	Males (n=28)		Females (n=21)		Total * (n=49)	
	no.	%	no.	%	no.	%
Celiac trunk	27	96.43	20	95.24	47	95.92
Aorta	1	3.57	1	4.76	2	4.08

*** The common hepatic artery was absent in one case.**

TABLE - 2

Prevalence of various sources of origin of the normal, replaced and accessory right hepatic arteries from different sites and according to gender

Source of origin of the right hepatic artery (RHA)	Males (n=29)		Females (n=21)		Total (n=50)	
Single right hepatic artery	**no.**	**%**	**no.**	**%**	**no.**	**%**
From proper hepatic artery	19	65.52	17	80.95	36	72
Replaced RHA from superior mesenteric artery	4	13.78	1	4.76	5	10
Replaced RHA from celiac artery	1	3.45	0	0	1	2
Replaced RHA from gastroduodenal artery	1	3.45	0	0	1	2
TOTAL	**25**	**86.20**	**18**	**85.71**	**43**	**86**

Double right hepatic artery	no.	%	no.	%	no.	%
From proper hepatic artery & accessory RHA from celiac artery	2	6.90	1	4.76	3	6
From proper hepatic artery & accessory RHA from superior mesenteric artery	2	6.90	2	9.52	4	8
TOTAL	**4**	**13.80**	**3**	**14.28**	**7**	**14**

Note- RHA = Right hepatic artery

TABLE - 3

Prevalence of variable relationship of the single right hepatic artery with the portal vein and the common hepatic duct in males and females

Relationship with the portal vein and common hepatic duct		Males (n=25)		Females (n=18)		Total (n=43)	
		no.	%	no.	%	no.	%
Relationship to portal vein	Anterior	22	88	17	94.44	39	90.70
	Posterior	3	12	1	5.56	4	9.30
Relationship to common hepatic duct	Anterior	2	8	6	33.33	8	18.60
	Posterior	23	92	12	66.67	35	81.40

TABLE - 4

Prevalence of different sources of origin of normal, replaced and accessory left hepatic artery according to gender

Site of origin of the artery	Males (n= 29)		Females (n= 21)		Total (n= 50)	
Single left hepatic artery	no.	%	no.	%	no.	%
From proper hepatic artery	23	79.31	17	80.95	40	80
From common hepatic artery	3	10.34	3	14.29	6	12
Replaced LHA from left gastric artery	1	3.45	1	4.76	2	4
TOTAL	**27**	**93.1**	**21**	**100**	**48**	**96**
Two left hepatic arteries	no.	%	no.	%	no.	%
From proper hepatic artery & accessory LHA from left gastric artery	1	3.45	0	0	1	2
From common hepatic artery & accessory LHA from left gastric artery	1	3.45	0	0	1	2
TOTAL	**2**	**6.9**	**0**	**0**	**2**	**4**