ijlpr 2022; doi 10.22376/ijpbs/lpr.2022.12.5.L229-236

International Journal of Life science and Pharma Research

ISSN 2250-0480

A CT Angiographic Study on the Variations of the Hepatic Arteries in the Living Liver Donors of the South Indian Population.

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Abstract: Living liver donor transplantation is the last option for the end stage liver diseases. The variations in the hepatic artery of the liver donor may lead to poor outcome, or may end with major post-operative complications such as hepatic artery thrombosis. To prevent the post-operative complications and to increase the success rate of the liver transplant surgeries, CT evaluation of the hepatic arteries is essential. Thus, the present study was aimed to study the variations of the hepatic arteries in the living liver donors. A total of 200 CT angiograms were collected from the department of Radiology from August 2018 to December 2021, and the evaluation was carried out in the Department of Anatomy, Deccan College of Medical Sciences, Hyderabad. All the CT angiograms were studied for the variations of hepatic arterial system, and the observed variations were noted and the incidence was calculated. The normal anatomy was observed in 62.5% liver donors and 37.55% of liver donors showed variations in hepatic arterial pattern. The incidence of the replaced left hepatic retry, replaced right artery, replaced left along with replaced right hepatic artery was observed as 11.5%, 9.5% and 3% respectively. The incidence of left and right accessory hepatic arteries was 7% and 4% respectively and the replaced right hepatic artery with accessory left hepatic artery was observed in 1.5% cases. The variations observed in the hepatic arterial pattern observed in this study could be helpful to the surgeons, while planning and selecting the suitable liver donors and also may minimise the risk and increase the success rate.

Keywords: Hepatic Artery, Celiac Truck, Living Liver Donor, CT Angiography

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Received On 13 May, 2022

Revised On 29 July, 2022

Accepted On 5 August, 2022

Published On 1 September, 2022

Funding This research did not receive any specific grant from any funding agencies in the public, commercial or not for profit sectors.

Citation P. Ashok ,Gunapriya Raghunath,V. Anantha Kumari and B. H. Shiny Vinila , A CT Angiographic Study on the Variations of the Hepatic Arteries in the Living Liver Donors of the South Indian Population..(2022).Int. J. Life Sci. Pharma Res.12(5), L229-236 http://dx.doi.org/10.22376/ijpbs/lpr.2022.12.5.L229-236

1. INTRODUCTION

Approximately 2 million people are dying with liver disease annually worldwide, and in that 1 million deaths are due to cirrhosis and another 1 million deaths are due to viral hepatitis or hepatocellular carcinoma. Liver cirrhosis is the 11th most common cause of the death and liver cancer is 16th most common cause of death globally. The liver disease related deaths accounts for 3.5% of all the deaths globally.[1] Liver transplantation has become the most preferred choice of treatment for the end stage liver diseases such as liver cirrhosis, hepatocellular carcinoma and acute or chronic liver failures.[2] The cadaveric donations of the livers for the transplant surgeries are not meeting the demand as the numbers of recipients are increasing rapidly in recent years.[3] The alternative option is the living liver donors, who are generously willing to donate their liver for their dear ones though there is a risk of morbidity. The two main principles to be remembered in the living liver donor transplantation are minimizing the morbidity and mortality of the donor and graft and recipient survival. So, it is very important to take all the necessary precautions to reduce the risks to the living liver donors and at the same time maximize the benefits to the recipient.[4] The living liver donor has to undergo an evaluation protocol of medical and psychological evaluation process and very importantly precise anatomical study of the liver including its arterial supply. The published evaluation protocols of living donor's liver transplantation show similarity across the globe.[4-7] Arterial variations are quite common as they develop in situ and anastomose with the neighbouring arteries. The classification on the anatomical variations and branching pattern of the celiac trunk was developed by Michel in 1955 after dissecting 200 cadavers. Later in 1966, Michel proposed an international classification system for the anatomical variations of the hepatic artery and classified them into 10 basic types.[8-10] Liver is supplied by the left and the right hepatic arteries; these are the branches of the common hepatic artery which is in turn a branch of the celiac trunk. The celiac trunk ventral branch of abdominal aorta originates just below the aortic hiatus at the level of T12 and L1 vertebrae and after its origin, it trifurcates into the left gastric artery, common hepatic artery and splenic artery in most of the individuals and considered as the normal branching pattern.[11] The recent advances in the imaging and radiological techniques such as computed tomography and angiography made easier for the surgeons in their treatment planning and ultimately reduces the morbidity and mortality.[12] Computed Tomography angiography has become the first step in the evaluation of abdominal vascular pathologic features because of its speed, high spatial resolution, and ability to depict associated extra-arterial structures.[13] The hepatic arterial system must be assessed by CT angiogram during the process of selection of the living liver donor to avoid intraoperative or postoperative complications. Previous authors studied the variations of the branching pattern of celiac trunk and hepatic arteries in different population groups like Egyptians, West Indians.[14,15] Studies on the variations of the hepatic arteries in living liver donors in south Indian population are rare. Thus the present study was undertaken to find the incidence of the hepatic arterial variations in the living liver donors.

2. MATERIALS AND METHODS

The present study was a retrospective observational study consisting of 200 CT angiograms of living liver donors conducted from August 2018 to January 2022 in the Department of Anatomy, Deccan College of Medical Sciences, Hyderabad, Telangana, India. The mean age of the participants was 33.35 years, with the range of 22 to 55 years. Among these, 104 were male donors and 96 were female donors. Three cases were cancelled for the liver donation as they were not suitable for the transplant surgery. All the angiograms were observed for the variations in the celiac trunk and hepatic arterial system and the variations were recorded. The study was approved by the institutional ethical committee (IRB No: 2018/23/015). Michel's classification was adopted to classify the observed variations. Type 1: Normal anatomy, where the common hepatic artery divides into proper hepatic artery (PHA) and the gastro duodenal artery (GDA), and the hepatic artery proper divides into right hepatic artery (RHA) and left hepatic artery (LHA). Type 2: Replaced left hepatic artery where the LHA originates from the left gastric artery (LGA). Type 3: Replaced right hepatic artery where the RHA originates from superior mesenteric artery (SMA). Type 4: Replaced RHA and replaced LHA. Type 5: Accessory LHA. Type 6: Accessory RHA. Type 7: Accessory RHA along with accessory LHA. Type 8: Replaced RHA with accessory LHA or Replaced LHA with accessory RHA. Type 9: Common hepatic artery (CHA) from SMA. Type 10: CHA from LGA.

3. RESULTS

The normal was observed in 62.5% cases of liver donors. The variations were classified as per the basic hepatic arterial pattern proposed by Michel. The incidence was noted in the table 1 and also compared with the Michel's study. The most common variation observed was replaced left hepatic artery that was observed in 11.5% of cases (Figure 2). The next common variation was replaced RHA observed in 9.5% of cases (Figure 3). The replaced LHA and replaced RHA were observed in 3% cases of liver donors (Figure4). The accessory LHA was more common than the accessory RHA and the incidence of the accessory LHA was observed in 7% of cases (Figure 5). The incidence of the accessory RHA was observed as 4% in that, accessory RHA originated from 2 sources: In 2.5% cases accessory RHA was originated from SMA (Figure 6) and in 1.5% cases accessory RHA was originated from LHA (Figure 7). Replacing RHA with accessory LHA was observed in 1.5% cases (Figure 8). The replace left hepatic artery and the right hepatic artery was arising from the celiac trunk in 0.5% case (Figure 9).

Table 1: Showing the incidence of the variations of the hepatic artery in living liver donors.

Type	Variation description	Incidence of variation
I	Normal anatomy	125 (62.5%)
II	Replaced left hepatic artery	23 (11.5%)
III	Replaced right hepatic artery	19 (9.5%)
IV	Replaced left hepatic artery and replaced right hepatic artery	6 (3%)

V	Accessory left hepatic artery	14 (7%)
VI	Accessory right hepatic artery	8 (4%)
VII	Accessory right hepatic artery and accessory left hepatic artery	1 (0.5%)
VIII	Replaced right hepatic artery with accessory left hepatic artery / Replaced LHA with accessory RHA	3 (1.5%)
IX	Common hepatic artery from Superior mesenteric artery	0 (0%)
X	Common hepatic artery from Left gastric artery	0 (0%)
XI	(Any other) Replace left hepatic artery and the right hepatic artery was arising from celiac trunk.	1 (0.5%)

Table1: Illustrates the incidence of the variations in the hepatic arterial pattern. Normal anatomy (Type 1) where the right and left hepatic arteries arise from the hepatic artery proper and hepatic artery proper was originated from the common hepatic artery along with gastroduodenal artery was observed in 62.5% cases. Type 2 that is replaced left hepatic artery was the most common variation observed with 11.5% incidence. The incidence of the accessory left hepatic artery was higher than the accessory right hepatic artery. Replaced left hepatic artery and the right hepatic artery arising from the celiac trunk was a novel variation observed with 0.5% incidence. Type IX and X were not observed in this study.

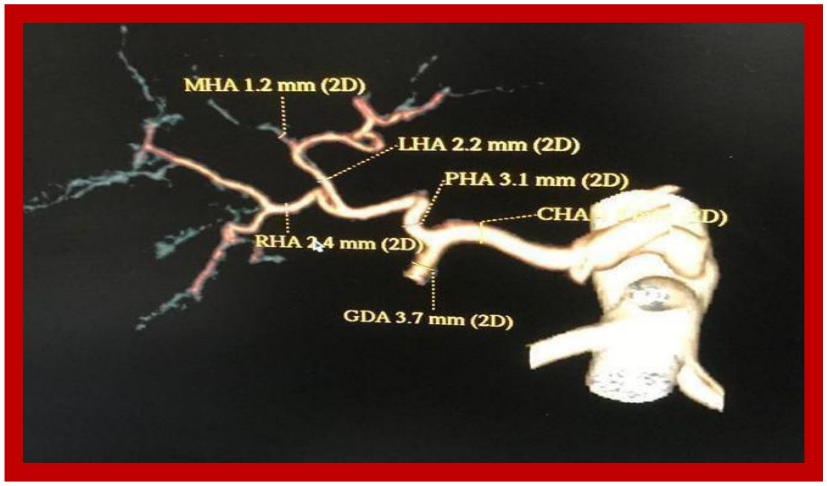

Fig 1: Showing normal vascular anatomy of liver

Figure 1 Shows the Type 1 arterial pattern where the common hepatic artery arising from the celiac trunk. Common hepatic artery branches into proper hepatic artery and gastroduodenal artery. The proper hepatic artery divided into the right and the left hepatic arteries.

Fig 2: Showing replaced left hepatic artery

Figure 2 Shows the Type II arterial pattern where the left hepatic artery arising from the left gastric artery instead of proper hepatic artery. Origin of the left hepatic artery from left gastric artery is called as replaced left hepatic artery. Proper hepatic artery continued as the right hepatic artery and gave a branch called the middle hepatic artery.

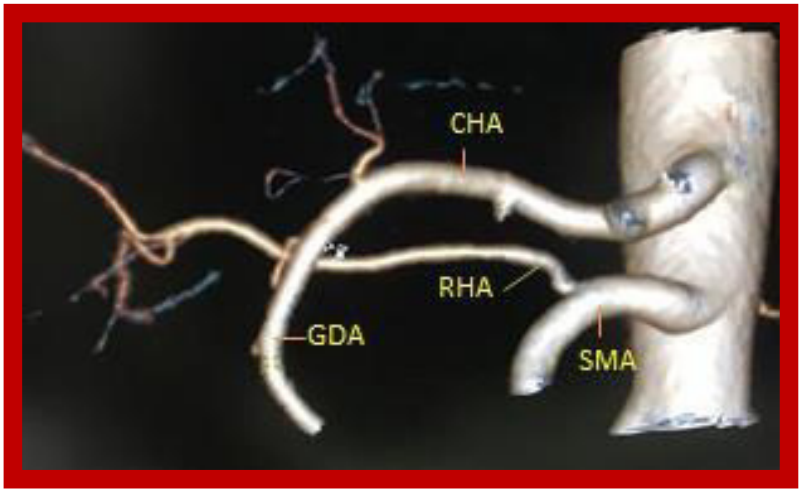

Fig 3: Showing replaced right hepatic artery

Figure 3 Shows the Type III arterial pattern where the right hepatic artery was arising from the superior mesenteric artery instead of proper hepatic artery. This pattern is called as replaced right hepatic artery. Normally, common hepatic artery divides into gastroduodenal artery and proper hepatic artery. The proper hepatic artery divides into the right and the left hepatic arteries.

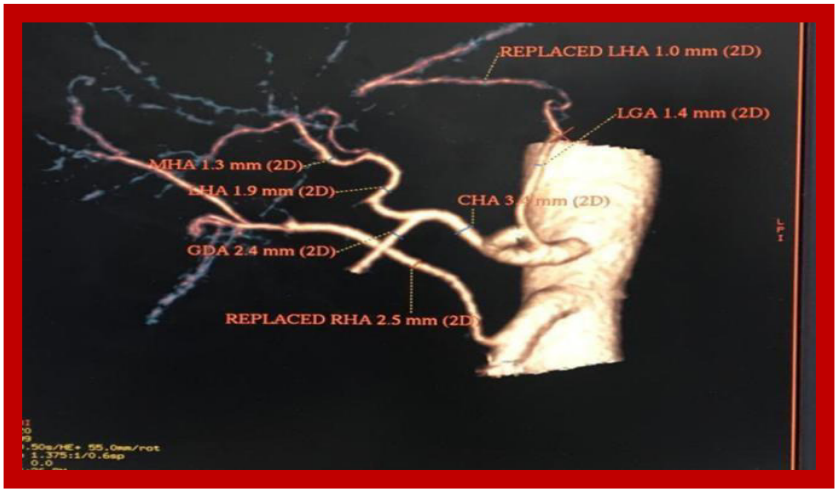

Fig 4: Showing replaced left hepatic artery and replaced right hepatic artery.

Figure 4 Shows the type IV arterial pattern where the left hepatic artery was arising from the left gastric artery that is called as replaced left hepatic artery and the right hepatic artery was arising from the superior mesenteric artery. The middle hepatic artery was seen as the continuation of the proper hepatic artery.

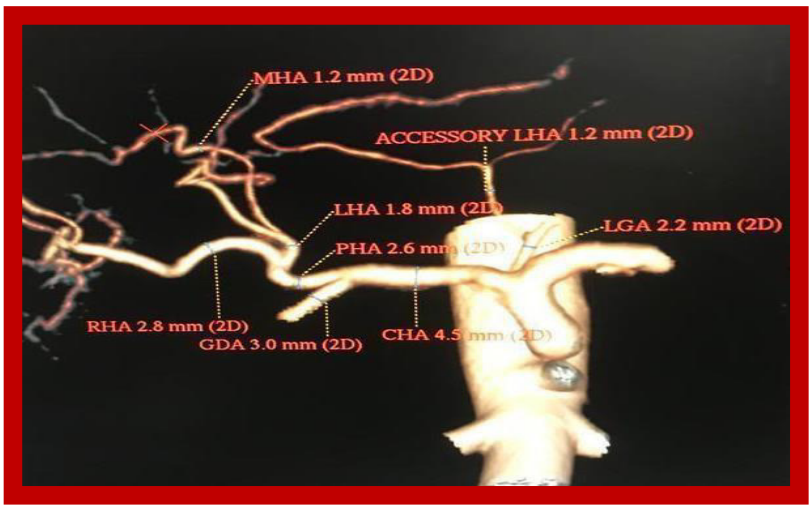

Fig 5: Showing accessory left hepatic artery.

Figure 5 Shows Type V arterial pattern where an accessory hepatic artery was arising from the left gastric artery. On the other side the common hepatic artery divided into gastroduodenal artery and proper hepatic artery and the proper hepatic artery divided into the right and the left hepatic arteries.

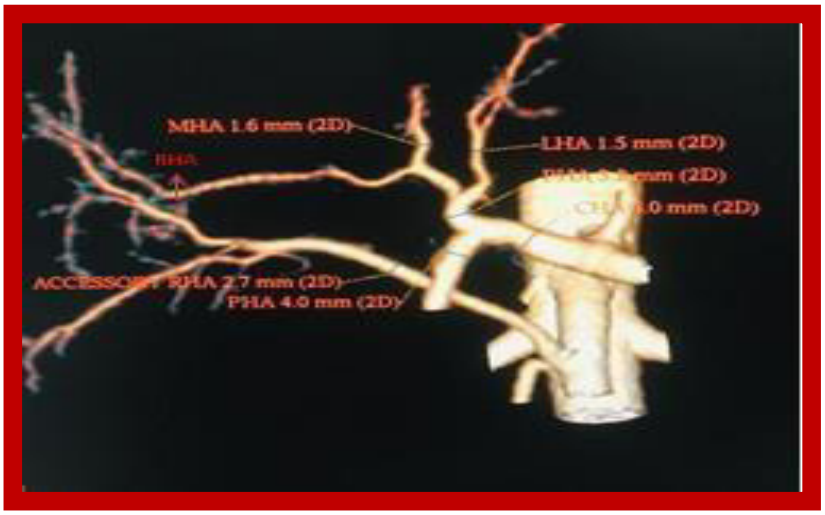

Fig 6: Showing accessory right hepatic artery from superior mesenteric artery

Figure 6 Shows type VI arterial pattern where an accessory right hepatic artery was arising from the superior mesentric artery. On the other side the proper hepatica retry was divided into the right and the left hepatic arteries.

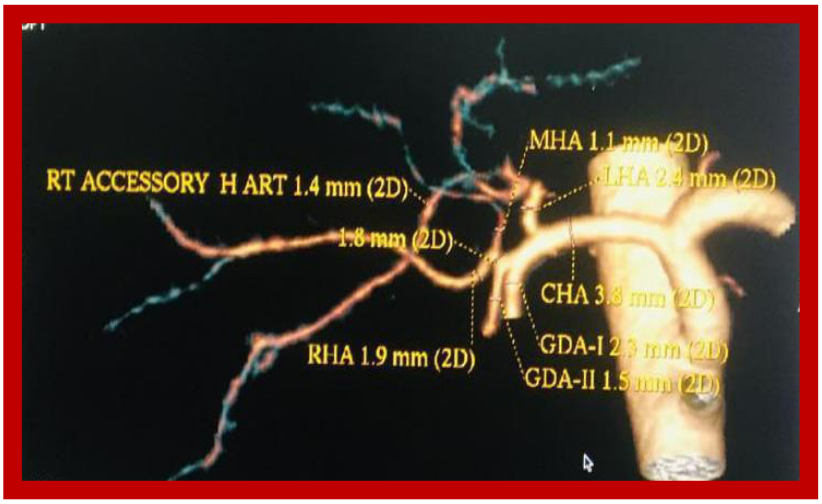

Fig 7: Showing accessory right hepatic artery from left hepatic artery

Figure 7 Shows Type VII arterial pattern where the common hepatic artery gave 2 gastroduodenal arteries, the left hepatic artery and the right hepatic artery. An accessory right hepatic artery was arising from the left hepatic artery.

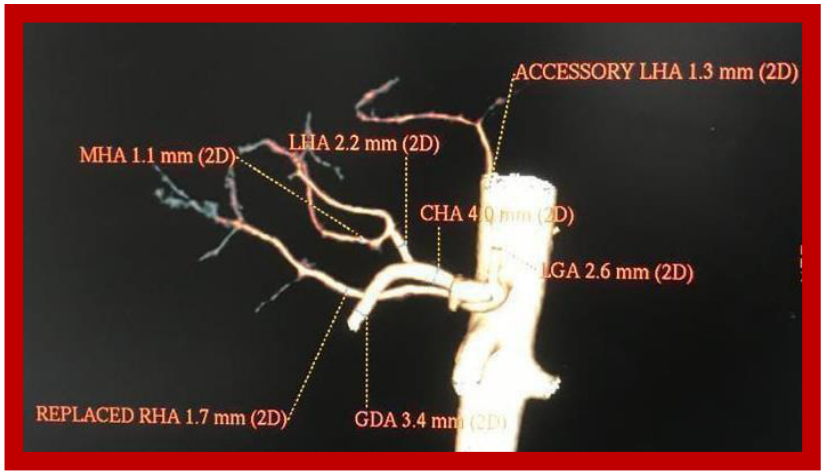

Fig 8: Showing replaced right hepatic artery with accessory left hepatic artery

Figure 8 Shows Type VIII arterial pattern where the replaced right hepatic artery was arising from the abdominal aorta along with the celiac trunk and an accessory left hepatic artery was arising from the left gastric artery.

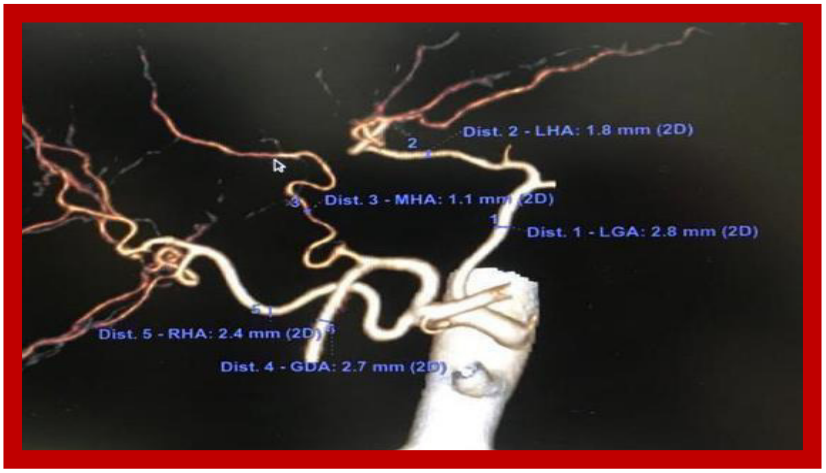

Fig 9: Showing replaced left hepatic artery and right hepatic artery arising from coeliac trunk.

Figure 9: Shows type XI arterial pattern and very rare variation where the replaced left hepatic artery was seen arising from the left gastric artery and the right hepatic artery was arising from the celiac trunk.

4. DISCUSSION

The prevalence of anatomical variations of hepatic arteries was reported as 13% to 48% in previous studies. The anatomical variations in hepatic arteries can be of great importance when planning liver transplant and donor selection process.[16,17] The hepatic arterial pattern must be demonstrated in the process of selecting the liver donor, as it is not possible to determine the vascular variations while performing the surgeries. Evaluating the variations of the hepatic arterial system by CT angiogram may recognise the need of the reconstruction of the hepatic arteries in liver transplant surgeries.[18] In the present study standard anatomy of hepatic arterial pattern was observed in 62.7% of liver donors and the incidence of the variations was observed in 37.5% of liver donors which is correlating with the other studies where Schroering et al., Rafael Lo´pez-Andu´jar et al., and Zaki et al., reported the incidence of the variations of the hepatic arterial pattern in 32%, 30% and 26.2% respectively whereas Brasil et al., observed variations in hepatic arteries only in 18% of CT angiograms that was much lesser than the present study that indicates that the higher incidence of variations.[12,14,19,20] Kishi et al., and Winston et al., had reported the incidence of the standard hepatic arterial pattern as 55% and 51% respectively.[21,22] Winston et al., reported single arterial variation of hepatic arteries as 44% and multiple arterial variations as 6% that shows higher incidence of the variations when compared to the present study. [22] Brasil et al., had studied the variations of the celiac trunk and hepatic arteries using CT angiograms of the patients referred for different conditions of the abdomen but not the living liver donors whereas in the recent study all the Ct angiograms of the living liver donors were considered. Brazil et al., have reported the standard anatomy in 82 % of cases and also identified 6 (Type 2, 3, 5, 6, and 11) variations of hepatic arterial anatomy. Among all the replaced right hepatic artery was reported to be more common with 10% of the incidence and the common hepatic artery originating from the superior mesenteric artery was the next common variation with 4% of the incidence. These results were in contrast to the results of the present study where the standard anatomy was observed in 68% of liver donors and identified 8 (Type 2,3,4,5,6,7,8 and 11) variations. In the present study, the variations of the left hepatic artery were predominant with 11.5% of incidence and the replaced right hepatic artery was the next common type. [12] Karakoyun et

al., had reported the incidence of the variations of left hepatic artery as 45.3% and right hepatic artery as 38.5% which is similar with the results of the present study where the variations of the left hepatic artery were more than the right hepatic artery. [23] In the present study the incidence of replaced RHA (Type 3) was observed in 9.5% and the accessory RHA was observed in 4% cases. The type 3 that is an accessory/replaced RHA is of most important type as it always requires an arterial reconstruction.[19] Perez-Saborido et al., had studied hepatic arterial pattern in 325 living liver donors and recipients and they reported the most common variation observed in donors was replaced right hepatic artery with the incidence of 38.2% cases which is followed by the replaced left hepatic artery in 35.3% cases. In the present study the incidence of the left hepatic arteries is higher than the right hepatic arteries. [24] Hiatt et al., classified hepatic arterial pattern into 6 types. The incidence of the variations observed in his study are as follows; Standard anatomy was considered as type 1 and reported in 75.7% of cases, replaced or accessory right hepatic artery arising from the superior mesenteric artery was considered as type 2 and reported in 10.6% cases, replaced or accessory left hepatic artery arising from the left gastric artery was considered as type 3 and reported in 9.7% of cases, the right and left hepatic arteries originating from the superior mesenteric and left gastric arteries respectively was considered as type 4 and reported in 2.3% cases, the entire common hepatic artery originating from the superior mesenteric artery was considered as type 5 and reported in 1.5% cases, and the common hepatic artery arising directly from the aorta was considered as type 6 and observed in 0.2% of cases. In the present study the replaced and the accessory right and left hepatic arteries were considered separately and the 9 variations were observed along with that the frequency of the variations was observed to be more in the present study.[25] In liver transplantation surgeries, the hepatic arterial complications such as hepatic artery thrombosis have a significant effect on mortality and morbidity. [26] Literature suggests that the donor hepatic arterial variations may needs complex arterial reconstruction that might be associated with a higher incidence of arterial complications.[19] As per the literature, the most commonly reported hepatic arterial pattern as per Michel's classification is type 3 that is replaced right hepatic artery which was reported between 6 to 15.5% followed by type 2 that is replaced left hepatic artery with the incidence range between 2.5 to 10%.[27-29] Thangarajah , Parthasarathy et al., studied the hepatic arterial variations in south Indian population and found type 5 as the most common variation whereas in the present study type 2 was the most common variation. [30] In the present study , in one case a very rare variation was reported that, the right hepatic artery was originated from the celiac trunk and the left hepatica retry was arising from the left gastric artery Behera et al., reported the same type of variation in a case report where they reported this while performing pancreaticoduodenal procedure and stated that the pancreaticoduodenectomy procedure itself is very complicated over that the vascular variations increase the risk of inadvertent vascular injury or ligation that may result in increased blood loss and prolonged operation time. [31] So, it shows that the necessity of the preoperative CT evaluation of the hepatic arterial anatomy to prevent intra and postoperative complications in the living liver donors.

5. CONCLUSION

With the results of the present study, we could conclude that, the evaluation of living liver donors by multi detector CT angiogram is of great value as it detects the vascular variations of hepatic arterial system before planning and selecting the donors which may contribute to minimise the potential risk and gain success in the liver transplant surgeries.

6. ACKNOWLEDGEMENT

We would like to acknowledge the Department of Radiology, Deccan college of medical Sciences and Global Hospitals for providing the resources and support.

7. AUTHOR CONTRIBUTION STATEMENT

Dr P Ashok Dr Gugapriya Ranganathan had idea on concept and study design. Dr P Ashok contributed in the sample collection, data analysis, result interpretation, Dr B H Shiny Vinila contributed in the literature survey and the manuscript writing, Dr Gugapriya Ranganathan had edited the manuscript.

8. CONFLICT OF INTEREST

Conflict of interest declared none.

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