Original Article

Computed Tomography Evaluation of the Arterial Supply to Segment 4 of the Liver

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ABSTRACT

Introduction: In a setting of living-donor liver transplant and patients undergoing extended hepatic resections for both primary and metastatic liver tumors, preoperative assessment of hepatic arterial anatomy is very important because of the risk of ischemic complications in the event of inadvertent injury to the arterial supply. Anatomical variations in hepatic arterial supply to the liver are very common and seen in nearly half the population. Identifying anomalous origin of segment 4 hepatic artery is vital since this vessel can cross the transection plane and can result in liver ischemia and liver failure. The purpose of our study is to study the variations in hepatic arterial anatomy to segment 4 of the liver in the Indian population. **Materials and Methods:** A retrospective evaluation of 637 consecutive computed tomography (CT) angiograms over a period of 1 year was performed, and we analyzed the arterial supply to segment 4 of the liver. **Results:** We found that the arterial supply to segment 4 of the liver originated from left hepatic artery (LHA) in majority of cases, 76.3%. LHA along with the accessory LHA supplied this segment in 6.4%, whereas the accessory LHA solely supplied this segment in 0.4%. The right hepatic artery (RHA) was seen to supply this segment in 10.2%. Dual supply with branches from the RHA and LHA was seen in 6.6% of patients. **Conclusion:** Preoperative mapping of segment 4 hepatic arterial supply using CT angiography will act as a roadmap to surgeons as they attempt to carefully dissect and preserve this segments' arterial supply. Depending on the anatomical variation, surgical techniques will vary to ensure safety of segment 4 arterial supply.

KEYWORDS: *Arterial supply, computed tomography angiography, segment 4*

INTRODUCTION

In a setting of living-donor liver transplant and patients undergoing extended hepatic resections for both primary and metastatic liver tumors, preoperative assessment of hepatic arterial anatomy is very important because of the risk of ischemic complications in the event of inadvertent injury to the arterial supply.

In adult living-donor liver transplant, the right lobe is commonly transplanted to a recipient. The plane of dissection for these patients is 1 cm to the right of the middle hepatic vein which is then extended inferiorly to the bifurcation of the right and left branches of portal vein.[1] In other instances, the left hemiliver or the left lateral segment is transplanted.

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After surgery, the donor liver volume reaches a critical limit, and hence, continued inflow to segment 4 is important to prevent liver failure. This is because in the postoperative period segment 4 accounts for up to 40% of the liver volume in the donor.[2] Anatomical variations in hepatic arterial supply to the liver are very common and seen in nearly half the population (45%),[3] with such variations occurring in segment 4 arterial supply in

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47%.[2] Identifying anomalous origin of segment 4 hepatic artery is vital since this vessel can cross the transection plane and can result in liver ischemia and liver failure.

The purpose of our study is to study the variations in hepatic arterial anatomy to segment 4 of the liver in the Indian population.

Materials and Methods

This study is a retrospective study conducted in a 2800-bedded tertiary care teaching hospital after Institutional Review Board (IRB) approval (IRB number: 11004) and informed consent was waived. A total of 637 consecutive patients who underwent computed tomography (CT) angiogram over a period of 1 year were included in the study.

The indications for the CT angiography are given in Table 1.

Following patients with CT angiograms were excluded:

1. Patients with masses which distorted the hepatic artery course
2. Patients with conditions which caused suboptimal opacification of segment 4 hepatic arterial branches such as celiac artery stenosis and median arcuate ligament syndrome and those with superior mesenteric artery stenosis
3. Suboptimal studies with poor contrast opacification of hepatic artery and studies with movement artifacts.

Multidetector 64 slice GE Discovery 750 HD scanner, Milwaukee, WI, USA, was used. CT images were acquired after administration of 80 ml of nonionic contrast, followed by a saline chase of 40 ml, at the rate of 4 ml/s. We used real-time bolus tracking technique, and our threshold was 150HU in the thoracic aorta. Our arterial phase started at a postthreshold delay of 7 s. Images were acquired at 0.625 mm and reconstructed at 2.5-mm slice thickness and 2.5-mm slice interval. The settings of the CT parameters included pitch of 0.9, 100 kVp, mA depending on automatic exposure control (Range 150-450 mA) to try to reduce radiation exposure and 0.5 s tube rotation. Maximum intensity projection (MIP) and three-dimensional volume-rendered (VR) images were done on the GE workstation. All postprocessing images were created on CT workstation (AW server).

Table 1: Indications for computed tomography angiography

Indication	*n*
Peripheral arterial occlusive disease	298
Voluntary kidney donor	145
Renal masses (RCC and angiomyolipoma)	36
Aortic aneurysm	20
Trauma	15
GI bleed	23
Mesenteric ischemia	47
Vasculitis	22
Postoperative/intra-abdominal bleeding	9
Tumor (bone, ovary, and GIST)	4
Pancreatitis	11
Miscellaneous (vascular malformation, neurofibromatosis, and preoperative assessment)	7

RCC: Renal cell carcinoma, GI: Gastrointestinal, GIST: Gastrointestinal stromal tumors

CT images were reviewed by two radiologists with 9 and 8 years of experience in consensus. Images were reviewed on Picture Archiving and Communication System (GE Centricity) software (Barrington, Illinois, USA). We assessed where the branch to segment 4 of the liver originated on axial images and if the segment 4 vessel was from a native or replaced/accessory hepatic artery. A replaced artery is an aberrant branch that substitutes for the absence of the native branch. An accessory artery is an aberrant branch in addition to the native artery, which usually courses along the path of the replaced hepatic artery. An accessory left hepatic artery (LHA) is one that arises from the left gastric artery, courses within the lesser omentum, and enters the liver in the umbilical fissure.

When the segment 4 branch originated from the right hepatic artery (RHA), we categorized it as intrahepatic, hilar, and extrahepatic. Intrahepatic was considered if the branch was within the liver parenchyma. A hilar branch was at the level of the hilum or <1 cm from the hilum. An extrahepatic branch is when the branch arose >1 cm from the hilum. Figure 1 is a schematic representation depicting extrahepatic, hilar, and intrahepatic branch from RHA to segment 4.

For patients with dual supply from both RHA and LHA to segment 4, we assessed the dominant arterial supply to the segment. We assessed this by comparing the diameter of the vessels.

Results

In the 637 patients whom we assessed, 215 patients were female and 422 patients were male. The median age was 50 years (range 7–86 years).

Table 2 gives the variations in the segment 4 arterial supply. Figure 2 is a schematic representation of the variations in the arterial supply to segment 4.

We found that the arterial supply to segment 4 of the liver originated from LHA in majority of cases, 486 patients (76.3%, n = 637). Of these patients, 454

(71.3%, *n* = 637) had supply from the native LHA and 32 (5.02%, *n* = 637) had a segment 4 vessel originating from a replaced LHA (arising from the left gastric artery).

Figure 3 is an MIP image of the LHA supplying segment 4 of the liver.

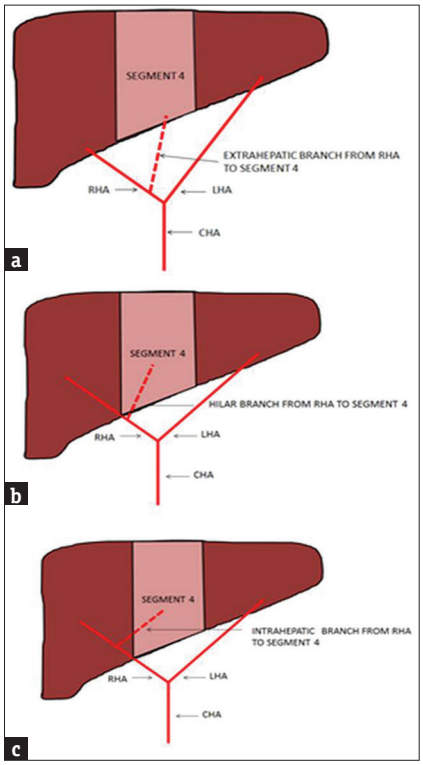

Figure 1: Schematic representation of the types of right hepatic artery supplying segment 4 of the liver showing (a) An extrahepatic branch from the right hepatic artery arising more than 1 cm from the hilum. (b) A hilar branch from the right hepatic artery. (c) An intrahepatic branch from the right hepatic artery.

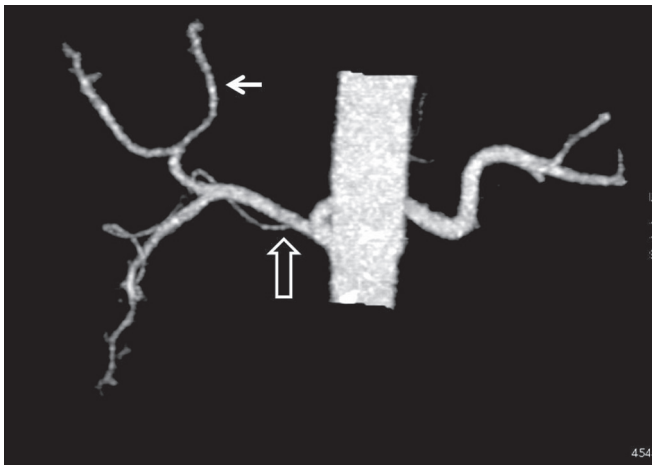

Figure 3: Maximum intensity projection images of a 62-year-old gentleman who underwent computed tomography angiogram for peripheral arterial occlusive disease showing left hepatic artery supplying segment 4 of the liver. Solid arrow – left hepatic artery and open arrow – common hepatic artery.

RHA was seen to supply this segment in 65 patients (10.2%, *n* = 637). In one of these patients, the segment 4 vessel originated from a replaced RHA from the superior mesenteric artery.

Figure 4 is a three-dimensional VR image of the RHA supplying segment 4.

We also evaluated the site of branching of the segment 4 artery from RHA.

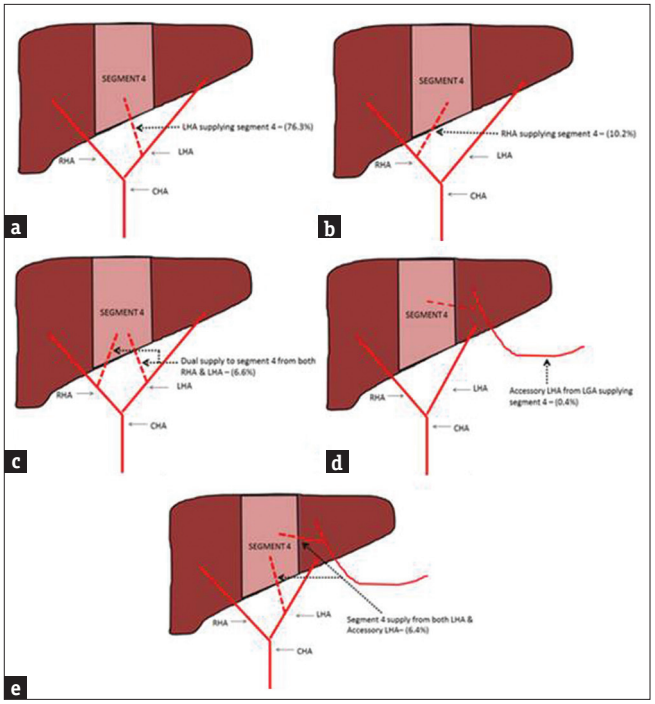

Figure 2: Schematic representation of the blood supply to segment 4 of the liver (a) Single branch from left hepatic artery as the most common vessel. (b) Single branch from the right hepatic artery being the second most common vessel. (c) Dual supply from both the right hepatic artery and the left hepatic artery. (d) Single branch from the accessory left hepatic artery arising from the left gastric artery. (e) Two branches, one each from the left hepatic artery and the accessory left hepatic artery.

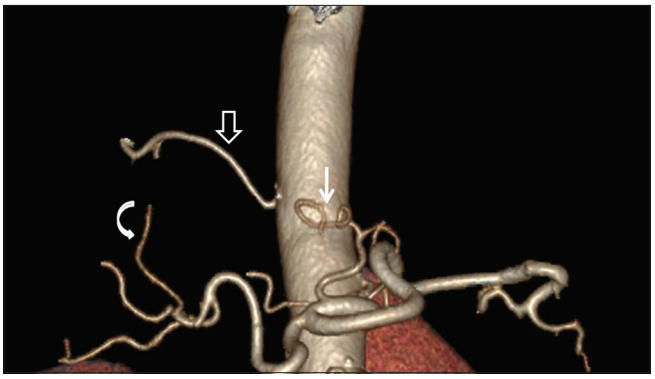

Figure 4: Three-dimensional volume-rendered image of a 69-year-old woman who underwent computed tomography angiogram of the abdomen for mesenteric ischemia showing supply from the right hepatic artery to segment 4 of the liver. Curved arrow – branch from the right hepatic artery, solid arrow – incidental replaced left hepatic artery, and open arrow – phrenic artery.

Table 2: Variations in segment 4 hepatic arterial supply

	n (%)
Left hepatic artery	486 (76.3)
Right hepatic artery	65 (10.2)
Dual supply from left and right hepatic artery	42 (6.6)
Left hepatic artery and accessory left hepatic artery	41 (6.4)
Isolated supply from accessory left hepatic artery	3 (0.4)

Of the 65 patients, none had an intrahepatic branch, 3 (0.47%, $n = 637$) had an artery from RHA at the level of the hilum and the remaining 62 patients (9.7%, $n = 637$) had an extrahepatic branch. Figure 6 shows an example of an extrahepatic branch of RHA supplying segment 4, and Figure 7 shows a hilar branch from RHA supplying segment 4.

Dual supply was seen in 42 patients (6.6%, $n = 637$) as seen in Figure 5. 9 patients (1.4%, $n = 637$) had a dominant supply from LHA and 7 patients (1.09%, $n = 637$) had a dominant supply from RHA. The rest of the 26 patients (4.08%, $n = 637$) had similar supply from both arteries.

An accessory LHA supplying segment 4 was seen in 3 patients (0.4%, $n = 637$).

Discussion

Preoperative knowledge of arterial supply to segment 4 is vital before living-donor liver transplant. It is also important in patients undergoing extended hepatic resection. Hence, it is important to know both normal and variant anatomy. The arterial supply to segment 4 of the liver is usually a branch that arises from LHA.[2] Michels, however, reported that the artery to segment 4 originated from RHA or LHA in similar proportions.[4] A postmortem cadaveric study by Jin et al., on the origin of segment 4 hepatic artery, found that the artery most commonly originated from RHA.[5] Hence, we can see that the reports on the origin of the segment 4 hepatic artery have been variable in the literature.

However, in our study, in 76.3% of patients, LHA supplied segment 4.

10.2% of our patients had a supply to segment 4 solely from RHA. Different studies have varying incidence with some being as high as 62.5%.[6] In these cases, RHA is clamped distal to the origin of the segment 4 artery to maintain adequate perfusion. Preoperative assessment of the length of the segment of the RHA distal to this vessel is important as it needs to be of sufficient length for anastomosis.[7]

In these patients, if the left lobe is being removed, then both the LHA and the artery supplying segment 4 are prepared for anastomosis to the recipient's arteries.

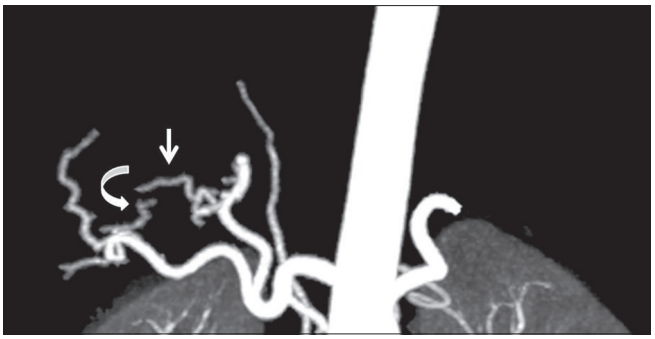

Figure 5: Maximum intensity projection image of a 30-year-old woman who underwent computed tomography angiogram of the abdomen for the assessment of colonic vascularity before repeat colonic pull through showing dual supply from the right hepatic artery and the left hepatic artery supplying segment 4 of the liver. Curved arrow – branch from the right hepatic artery and solid arrow – branch from the left hepatic artery.

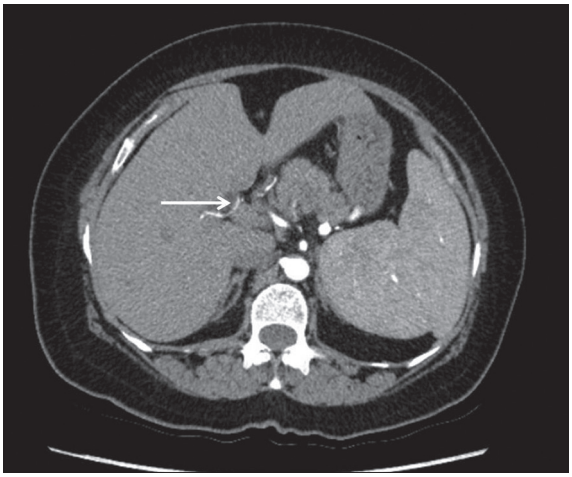

Figure 6: A 56-year-old woman, a voluntary kidney donor, underwent contrast-enhanced computed tomography axial sections of the abdomen which shows an extrahepatic branch from right hepatic artery supplying segment 4 as indicated by the arrow.

Figure 7: A 36-year-old gentleman with retroperitoneal mass underwent contrast-enhanced computed tomography axial sections of the abdomen which shows a hilar branch from the right hepatic artery (arrow) supplying segment 4 of the liver which is seen at a more cranial level.

Dual supply from both LHA and RHA was seen in 6.6%. Onishi et al., have reported that in 5.5% of cases, both LHAs and RHAs supplied segment 4.[8] In this situation, surgeons sacrifice the artery arising from RHA and anecdotal evidence suggests that segment 4 functions well after this.[9]

Conclusion

With many centers currently doing living-donor liver transplant and hepatic resections, knowledge of the arterial supply to segment 4 becomes important for the functioning of the remnant liver. In our study, we found that only 10.2% of the study population had RHA as the sole arterial supply for segment 4. Thus, preoperative mapping of segment 4 hepatic arterial supply using CT angiography will act as a roadmap to surgeons as they attempt to carefully dissect and preserve the supply to segment 4.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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