RESEARCH ARTICLE

Segment IV hepatic artery in potential donors for living related liver transplantation: Evaluation with multi-detector CT

Rashed Nazer, Ahmed Kamal Nasir Khan, Awais Ahmed, Mobeen Ahmed, Farheen Raza, Muhammad Salman Rafique

Abstract

Objective: To assess segment IV hepatic arterial anatomy and its variation on multi-detector computed tomography in potential liver donors.

Methods: The retrospective study was conducted at Shifa International Hospital, Islamabad and comprised data of potential liver transplant donors related to the period between January 2012 and June 2017. Computed tomography scans were performed using multi-detector scanners. Images were transferred to work station for post-processing and were analysed regarding the origination and variation of the arteries by two independent experienced radiologists.

Results: Of the 455 patients whose records were evaluated, 299(65.7%) were males and 156(34.3%) were females. Six types of segment IV artery were defined based on their points of origin: left hepatic artery 285(62.6%), right hepatic artery 111(24.4 %), proper hepatic artery 9(1.8 %), common hepatic artery 29(6.4%), gastro duodenal artery 3(0.7 %), and dual 18(4.1 %).313 of total cases (68.8%) had normal anatomy with no variation. Those with aberrant/variant anatomy constituted 142(31.2%) of the total.

Conclusion: Multi-detector computed tomography angiography was found to be a fast, reliable and non-invasive technique that could evaluate normal as well as anatomical variants of segment IV arteries.

Keywords: Segment IV artery, Accessory artery, replacedartery, Living related liver donor. (JPMA 69: 799; 2019)

Introduction

In view of the increase in demand of liver transplantation and shortage of cadaveric livers, surgeons switched from cadaveric transplantation to living donor liver transplantation (LDLT) in the 1990s.[1] This switchover is justified by increasing waiting time for suitable deceased organ, wait-list morbidity and mortality of transplant candidates. With the advent of this challenging new method, the utmost importance is to avoid endangering the vascular supply of the donors and not to alter their metabolic functions. Donor selection and evaluation should be thorough and highly specialised, because donor safety is imperative and can never be compromised regardless of the consequences and even death of the awaiting recipient. No exception to this rule is justified.[2] Because of various anatomic variations of hepatic artery which affects the surgical approach and future outcomes, it is necessary to get the complete donor and recipient liver vasculature mapping to get surgical guidance and to avoid bleeding, hepatic artery thrombosis, ischaemic cholangiopathy and other post-transplant complications.[3] In the era of LDLT, paying particular attention to the point of origin of segment IV artery is a prerequisite, especially when the lateral section is relatively small.

Multi-detector-row computed tomography (MDCT) has become a more valuable and minimally invasive revolutionary technique for the evaluation of hepatic arteries and its variations, which was formerly done by digital subtraction angiography (DSA).[4] The fast scanning capability limits motion artefacts and enables imaging of entire liver during a single breath hold.[2] It depicts detailed hepatic portal, venous and arterial anatomy, comprehend hepatic parenchymal status, measure graft and remnant liver volumes, defines virtual hepatectomy planes and other associated abdominal abnormalities.[5] MDCT is capable of acquiring images with slice thickness up to 0.5mm and provides excellent spatial and temporal resolutions. If the acquisition parameters and timing of the contrast bolus are optimised, this resolution even allows visualisation of a tiny artery.[6,7]

In classical anatomical arterial pattern, coeliac axis gives rise to left gastric artery (LGA) and then bifurcates into splenic artery and common hepatic artery (CHA). CHA divides into proper hepatic artery (PHA) and gastroduodenal artery (GDA). The PHA bifurcates into left hepatic artery (LHA) and right hepatic artery (RHA). Segment IV may be supplied by one or more branches arising from the LHA, the RHA, or from both.[8]

The hepatic arterial variants are very common and

Shifa International Hospital, Islamabad.

Correspondence: Ahmed Kamal Nasir Khan. Email: dr.ahmed1988@ymail.com

reported in approximately 42% cases. Common and rare hepatic arterial variants have also been described.[9,10] Segment IV arterial supply variations reported in literature are nearly 47%.[6,11] Various studies performed on cadaveric samples, angiography and MDCT have variable results. A study reported that this artery originates in equal proportion from LHA and RHA.[9] In many studies, segment IV artery is noted to be arising from LHA, while others have reported RHA being the main source artery. A smaller number of cases with variable results have been described for segment IV arterial supply from CHA, PHA or dual source.[12-14] These variations and inconsistency in data of hepatic arterial anatomy have a significant impact in surgical planning. The accurate definition of origin and course of artery to segment IV of liver is one of the crucial steps in LDLT imaging.[8] Hence, radiologist should be well aware of these anatomic variants.

The current study was planned to demonstrate anatomical variations of segment IV hepatic artery on MDCT in potential living donors.

Patients and Methods

The retrospective study was conducted at Shifa International Hospital, Islamabad and comprised potential liver transplant donors who underwent CT scan for transplant workup between January 2012 and June 2017. After obtaining permission from the institutional ethics committee, CT scans of all donors were reviewed. They showed appreciable contrast opacification of segment IV hepatic artery. Suboptimal contrast opacification and cases that did not reveal clear anatomy were excluded. Postsurgical cases, patients with portal vein thrombosis, arterio-venous malformations and other abdominal pathologies were also excluded.

CT scans were performed at 320 multi-detector CT scanner (Aquilion ONE TM 320 Slice CT). Donors were advised to come with proper fasting; minimal of 4hours. The complete scan included the acquisition of unenhanced series followed by arterial and portal venous phases. The whole examination took about 75-90s. A single breath hold volumetric scan was obtained following the dynamic injection of non-ionic low osmolar iodinated contrast material (Ultravist 300 or 370) at a dose of 2 ml/kg body weight. The contrast material was injected intravenously by means of an automatic power injector (StellantMedrad) at a rate of 4-5 ml/s. Computer-assisted bolus-tracking software was used to determine the optimal scan delay for each patient. For the hepatic arterial phase, scanning is automatically triggered at 180HU in the abdominal aorta at the coeliac artery level. The venous phase was acquired with an effective delay of 65s after initiation of the contrast material injection. MDCT parameters were: 160_0.5mm detector collimation; 0.5mm reconstruction thickness; 139 pitch; 120kVp tube voltage. Reconstructed images demonstrating various origins of segment IV hepatic artery in the patients were reviewed (Figure-1)(Page-801).

Data obtained was transferred to workstation (VitreaFx, Toshiba, Japan) for imaging post-processing and analysis. Images were reconstructed and analysed by two independent experienced radiologists. The interpretation of datasets was done on workstation, using axial sections as well as reconstruction algorithms, including maximum intensity projection (MIP), multiplanar reconstruction (MPR) and volume rendering (VR). Scans were first assessed for adequate contrast enhancement of artery to segment IV by visual assessment. It was confirmed that artery was clearly visualised and not be masked by any other visceral/venous structure. The compilation of data was done and origin of segment IV artery was documented in each patient, and the results were interpreted in terms of percentage.

For the purpose of the study, segment IV hepatic artery was defined as small branch of one of the main arteries particularly supplying segment IV of the liver. In literature, this artery has been given various names, including middle hepatic artery, left medial artery, medial segment artery and segment IV artery (A4).[15]

Classical normal anatomy was identified when artery to segment IV was getting its origin from LHA or RHA.

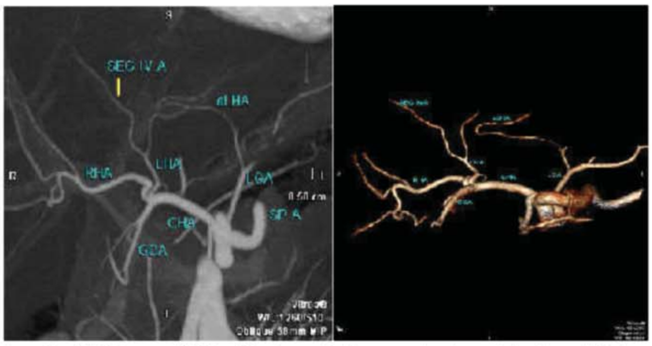
Replaced (r) origin of hepatic arteries referred to the arterial blood supply from an ectopic location. The rLHA and rRHA were identified when these arteries were arising from other than their normal anatomical location i.e. not from the CHA, and could be from LGA, superior mesenteric artery (SMA) or directly from the aorta.

Accessory (a) origin of hepatic arteries referred to the arterial blood supply from typical as well as ectopic branch. The aLHA and aRHA were identified when these arteries were present in addition to their anatomical counterparts and could be arising from any artery i.e. abdominal aorta or its branch.

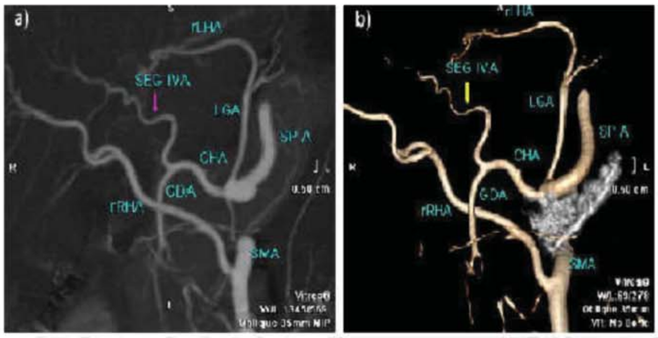
Dual supply referred to scenario when there were two separate arteries supplying segment IV individually. These arteries could be either normal two anatomical arteries, one normal anatomical and additional replaced/ accessory and/or both replaced/accessory.

Result

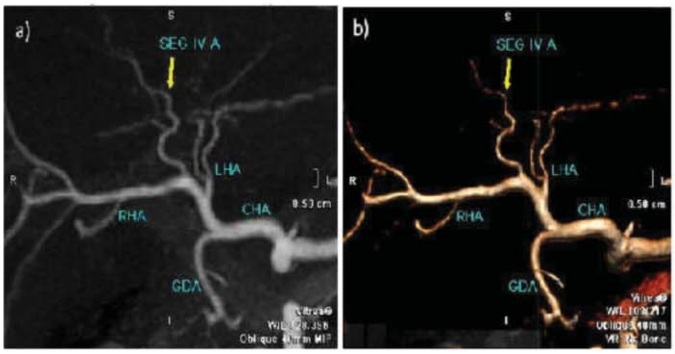
Of the 455 patients whose records were evaluated,



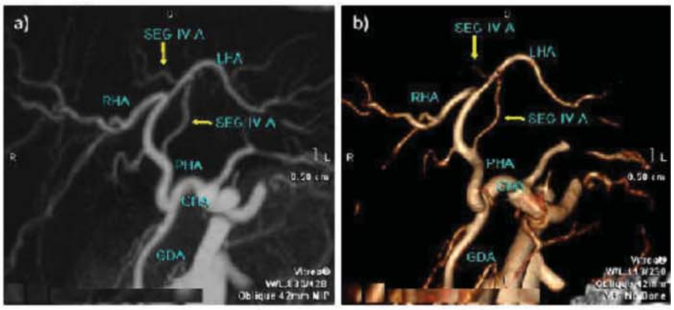
Case 1: a) MIP image. b) Vitra 3D reformatted image, showing origin of seg IV A form LHA in the presence of a LHA arising from LGA.



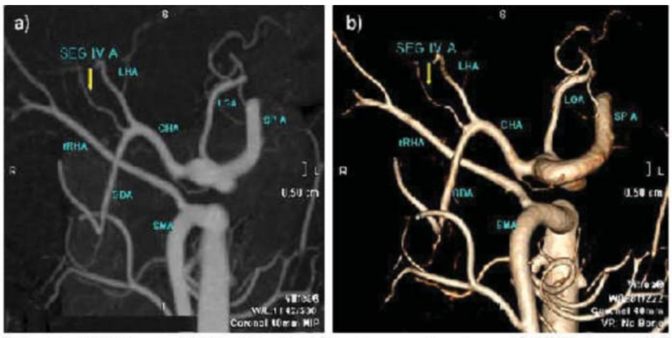
Case 3: a) MIP image. b) Vitra 3D reformatted image, showing origin of seg IV A from CHA where both LHA and RHA are replaced. rLHA is arising from LGA while rRHA is originating from SMA.



Case 2: a) MIP image. b) Vitra 3D reformatted image, showing origin of seg IV A from RHA in the presence of classical anatomy.



Case 4: a) MIP image. b) Vitra 3D reformatted image, showing origin of seg IV A from PHA in the presence of classical anatomy.



Case 5: a) MIP image. b) Vitra 3D reformatted image, showing origin of seg IV A from GDA (type peculiar to our study) in the presence of rRHA arising from SMA.

Figure-1: Types of segment IV artery were defined based on their points of origin.

299(65.7%) were males and 156(34.3%) were females. Six types of segment IV artery were defined based on their points of origin (Figure-2)(Page-802). In LHA type 285(62.6%) cases, segment IV artery arose from normal LHA with normal RHA in 200(70.2%) cases, form normal LHA with rRHA in 60(21%) cases. In aberrant LHA type,19(6.7%) from rLHA and 6(2.1%) from aLHA.

In RHA type, 111(24.4%) cases, segment IV artery arose from normal RHA with normal LHA in 88(79.3%), from normal RHA with rLHA in 20(18.0%).In aberrant RHA type, 3(2.7%) cases from rRHA.

In PHA type, 9(1.8%) cases, segment IV artery arose from normal PHA with normal LHA and RHA in 5(55.6%) case, from normal PHA with rLHA rRHA in 2(22.2%) cases, PHA with rRHA in 2(22.2%) cases.

In CHA type 29(6.4%) case, the segment IV artery arose from normal CHA with normal LHA and RHA in 5(17.2%) cases, from normal CHA with aberrant LHA/RHA in 24(82.8%) cases. Out of these, both RHA and LHA were replaced in 11(45.8%) cases, only rRHA in 6(25%) cases and only replaced LHA in 7(29.2%) cases.

In GDA type 3 cases (0.7%), segment IV artery arose from normal GDA with normal LHA and RHA in 1(33%) case, from normal GDA with rRHA in 2(67%) cases.

In dual type 18(4.1%) cases, segment IV artery arose from both RHA and LHA in 14(78%) cases, from RHA and rLHA 1(5.5%) case, from RHA and aLHA 1(5.5%) case, from PHA and rLHA 1(5.5%) case, from CHA and RHA in 1(5.5%) case.

Segment IV artery arising from normal LHA, RHA, CHA, GDA and PHA were found in 313(68.8%) cases, and those with variations were found in 142(31.2 %) cases.

Discussion

LDLT become technically possible in the 1990s. The new intervention saved a lot of lives but pushed donors into a

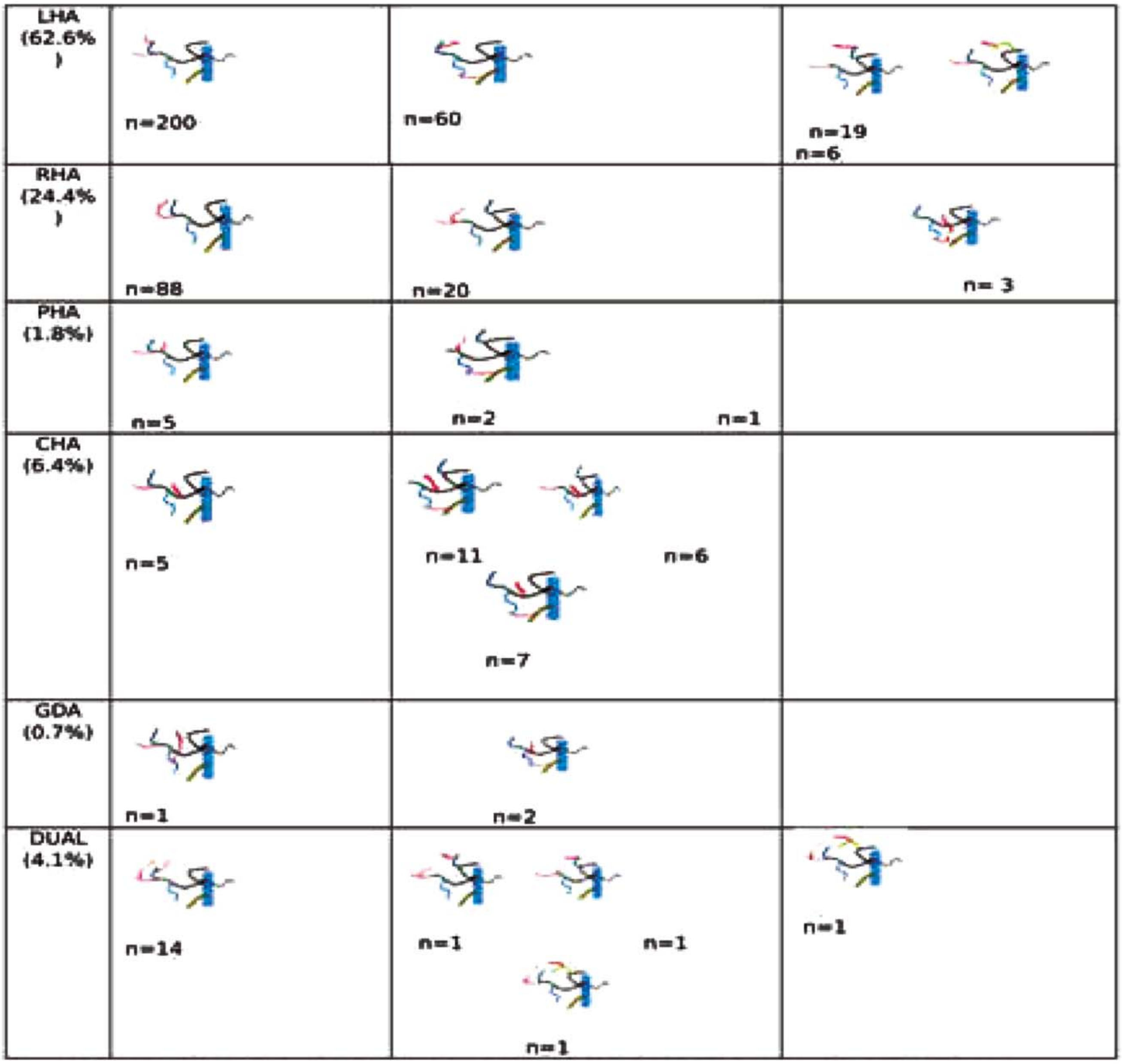


Figure-2: Illustration of arterial supply to segment IV in our study. LHA: Left Hepatie Artery RHA: Right Hepatic Artery GDA: Gastro Duoenal Artery PHA: Proper Hepatic Artery CHA : Common Hepatic Artery

great risk. The earlier studies in 2003 from Europe, Asia and the USA pointed out greater risk of mortality after right lobe donation. Post-operatively, liver insufficiency was found to be the main cause.[16]

LDLT is a complex procedure and it is essential for liver surgeons to have exact knowledge and comprehensive understanding not only of standard hepatic anatomy but also of variant hepatic anatomies of segment IV. Failure to demonstrate its proper origin and to miss any variant anatomy leads to serious complications like ischaemia. Hence, in right lobe LDLT it is important to preserve arterial supply to the remnant left lobe of the donor. If the inflow to segment IV arises from LHA, dissection is carried to the bifurcation of the PHA. If the inflow to segment IV arises from RHA, dissection is carried only as far as the branch to segment IV and the RHA is divided distal to it.[17,18] If the origin of the segment IV artery from RHA is not detected before the surgery and the RHA is clamped as it extends from the PHA, the left lobe medial segment that remains in the donor will develop ischaemia and the

Table: Comparison of our study results with other various international studies.

	Our Study (n=249) 320-section CT	XIE (n=453) 128-section CT	WANG (n=145) 64-section CT	SUREKA (n=600) 40-section CT	SABA (n = 1910) 4/16/40-row CT	SALISOY (n=52) 8-row CT	Kamel (n =40) 8-row CT	Lee (n =102) 4-row CT	ONISHI (n=171) Cadaveric study	JIN (n=62) Cadaveric study	YOSHIMURA (n=122) Angiographic study	KISHI (n=)
LHA	**62.6**	51.66	36.9	27.83	55.01	75	35	53	**61.5**	32.3	73	**62.5**
RHA	**24.4**	30.68	56.3	41.33	31.25	25	62.5	39	**27.5**	53.2	**27**	37.5
PHA	1.8	5.3	6	-	3.99	-		2	5.5	4.8		
CHA	6.4	-		4.5	-	-		-	-	-		
GDA	0.7	-		-	-	-		-	-	-		
Dual	4.1	12.14		-	9.14	-		6	5.5	9.7		
Triple	-	0.22		-	0.61	-		-	-	-		

LHA: Left hepatic artery
RHA: Right hepatic artery
PHA: Proper hepatic artery
CHA: Vommon hepatic artery
GDA: Gastroduodenal artery.

metabolic needs of the donor may not be met during the generation process. If LHA is replaced from LGA and RHA from SMA with segment IV hepatic artery arising from CHA, the segment IV together with the CHA and GDA can be procured for possible anastomosis in a left lobe allograft.[11]

MDCT with its post-processing techniques and excellent image rendering in two- and three-dimensional reconstruction planes have made it possible to visualise even a millimetre-sized vessel. Several studies have suggested a very good correlation between MDCT angiography and DSA.[15,19] Kamel et al. successfully demonstrated the application of MDCT in donor selection and surgical planning before living adult right lobe liver transplantation, and identified artery to segment IV in 39 patients out of 40.[12] Artioli et al. in 2010 documented sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) to be 100% in demonstrating hepatic arterial anatomy.[20] The current study was able to identify the origin and course of segment IV artery in all the cases.

There has been high degree of variability in the origin of the segment IV artery reported in the literature. The earlier studies showed that in majority of the cases the artery was arising from either LHA or RHA in approximately equal proportion. Some studies[11,21,13,12] reported RHA being the main source (43%, 41%, 53% and 62%) compared to others[12,22-25,18] where segment IV was mainly supplied by LHA (51%, 55%, 61%, 75%, 62.5% and 73%). In our study the segment IV artery was arising mainly from LHA (62.6%) followed by RHA (24.4%). Our results are close to a study in which the artery to segment IV had branched from LHA in 55% and from the RHA in 31% cases. The dual supply to segment IV was observed in about 4.1% cases which is close to a study (5.5 %)[24] but one study found it to be quite high at 12.14%.[22] CHA being the source for segment IV artery was seen in 6.4% cases which indicates significant number and is close to wat has been reported by one study,[21] while there are studies that did not report even a single such case.[22,24,25]

A peculiar finding observed in 3 cases in the current study is that GDA was the sole source of segment IV supply. To our knowledge, this anatomic variation is not described before in literature. No case of triple supply was identified in our study while it is reported earlier by two studies[22,23] in frequency of 0.2% and 0.61% respectively. The variability of segment IV hepatic arteries in the current study and those reported for cadaver studies and CTA series published in literature were also tabulated (Table).

On the basis of point of origin of segment IV artery, Wangin in 2010 described a classification system for segment IV artery focussing on the source artery mainly being either RHA or LHA. In 2008, Jin, based on his anatomic study on cadavers, and in 2014 Xie, on MDCT suggested a similar classification system with the addition of dual and triple supply to segment IV. We feel that the latter classification system is more comprehensive and radiologically appropriate for defining the segment IV artery. We added GDA type into this classification system based on our findings.

Conclusion

Artery to segment IV has diversity of variations in its origin and branching pattern. The importance of detailed pre-operative evaluation of LDLT cases cannot be overemphasised. MDCT angiography is the modality of choice to identify and explain all these anatomic variations and further help surgeons in planning their approach and anastomotic techniques to prevent complications and fatal outcomes with help of radiologists.

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Conflict of Interest: None.

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