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## Case Report

# A rare anatomic variation of an accessory right hepatic artery arising from the right inferior phrenic artery: A case report and review of literature<sup>☆</sup>

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## ABSTRACT

Living donor liver transplantation is a vital option for patients with limited access to deceased donor organs, but its success depends heavily on meticulous preoperative planning and an understanding of vascular anatomy. We present a rare case of hepatic arterial variations with an accessory right hepatic artery originating from the right inferior phrenic artery. Awareness of such anomalies is essential for transplant surgeons and radiologists to ensure optimal graft selection, minimize surgical complications, and improve both donor and recipient outcomes.

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## Introduction

Adult living donor liver transplant programs are becoming increasingly common due to the rising demand for liver transplants and the shortage of cadaveric liver donors. However, living donor hepatectomy is a technically challenging surgery

with associated risks. Therefore, a comprehensive evaluation is necessary for any potential donor before surgical consideration. The Organ Procurement and Transplantation Network (OPTN) donor evaluation process involves assessing specific anatomical parameters of living liver donors, including the projected graft volume, the donor's remnant liver volume, vascular anatomy, and the determination of suitability [1].

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Understanding hepatic vascular anatomy variations and their vascularization is crucial. A detailed vascular roadmap provides the operating surgeon with essential information, including an assessment of the hepatic parenchyma and segmental liver volumes, enabling more effective planning for a safe surgical approach. This is particularly important to aid with selecting the right donor and preventing intraoperative complications.

Donor hepatic artery variations, including accessory hepatic arteries, add complexity to liver transplantation procedures. Accurate identification, careful preservation, and appropriate surgical planning are essential to mitigate risks and optimize graft outcomes. Multidisciplinary coordination involving transplant surgeons, radiologists, and microsurgeons is critical to address these challenges effectively.

The normal hepatic arterial anatomy as described by Michel is seen approximately in 55%–76% of the population, while the remaining have a variant arterial anatomy reaching up to 50% of cases [2].

Identifying hepatic artery (HA) anatomic variations and accurately measuring the arterial length before bifurcation are vital aspects of surgical planning for graft procurement and reconstruction. These steps can be particularly challenging and complex, depending on the specific anatomic variation. Insufficient evaluation of these anatomical variants can result in severe perioperative and postoperative complications for both donors and recipients.

The presence of accessory arteries supplying a lobe necessitates 2 arterial anastomoses, which can prolong surgical time and elevate the risk of postoperative hepatic arterial thrombosis of the graft. These complications include inadvertent intraoperative injuries, excessive dissection, graft hypoperfusion, and a heightened risk of hepatic artery thrombosis [3].

Some centers consider the presence of 2 or more graft arteries as a relative contraindication to donation. Multiple arterial reconstructions, particularly involving small-diameter vessels, elevate the risk of thrombosis and biliary complications.

## Case presentation

We present a case of a 35 years old male who was undergoing liver donation evaluation at our facility. Evaluation included but was not limited to performing a preoperative CT angiography of the liver for assessment of the hepatic vasculature prior to liver donation.

He had no known medical or surgical history with a negative history of alcohol use. There were no risk factors for fatty liver or metabolic syndrome. He had a BMI of 24.6. Blood investigations didn't reveal any contraindications for liver donation.

The CT angiography showed the common hepatic artery originates from the celiac trunk which gives rise to the proper hepatic artery which in turn divides into right and left hepatic arteries. The right hepatic artery was predominantly supplying segments IV, V and VIII (Fig. 1).

There was an extremely rare origin of an accessory right hepatic artery arising from the right inferior phrenic artery. This accessory right hepatic artery was the dominant supply to segments VI and VII of the right hepatic lobe.

The patient was discussed in the Liver Transplant Selection Multidisciplinary meeting with the transplant surgeons, radiologists and hepatologists and he was deemed unfit for liver donation due to liver vascular anatomy.

## Discussion

Aberrant hepatic arteries are the most common variations of the common hepatic artery (CHA). They are divided into 2 types; the accessory hepatic artery and the replaced hepatic artery. A replaced hepatic artery typically arises from an anomalous origin and supplies a portion of the liver solely. It typically has a greater length, enabling the surgeon to perform anastomoses more safely.

An accessory hepatic artery (AHA) is defined as an additional artery supplying a liver segment along with the normal supplying hepatic branch and is often smaller but functionally essential, and has a specific distribution in every case.

The size of the recipient hepatic artery determines the arterial blood flow to the liver. A small-caliber recipient hepatic artery (3 mm or less) or multiple small hepatic arteries supplying the liver from different sources may result in inadequate arterial inflow to the graft after transplantation and may require an alternative inflow source, such as an aortohepatic interposition graft [4].

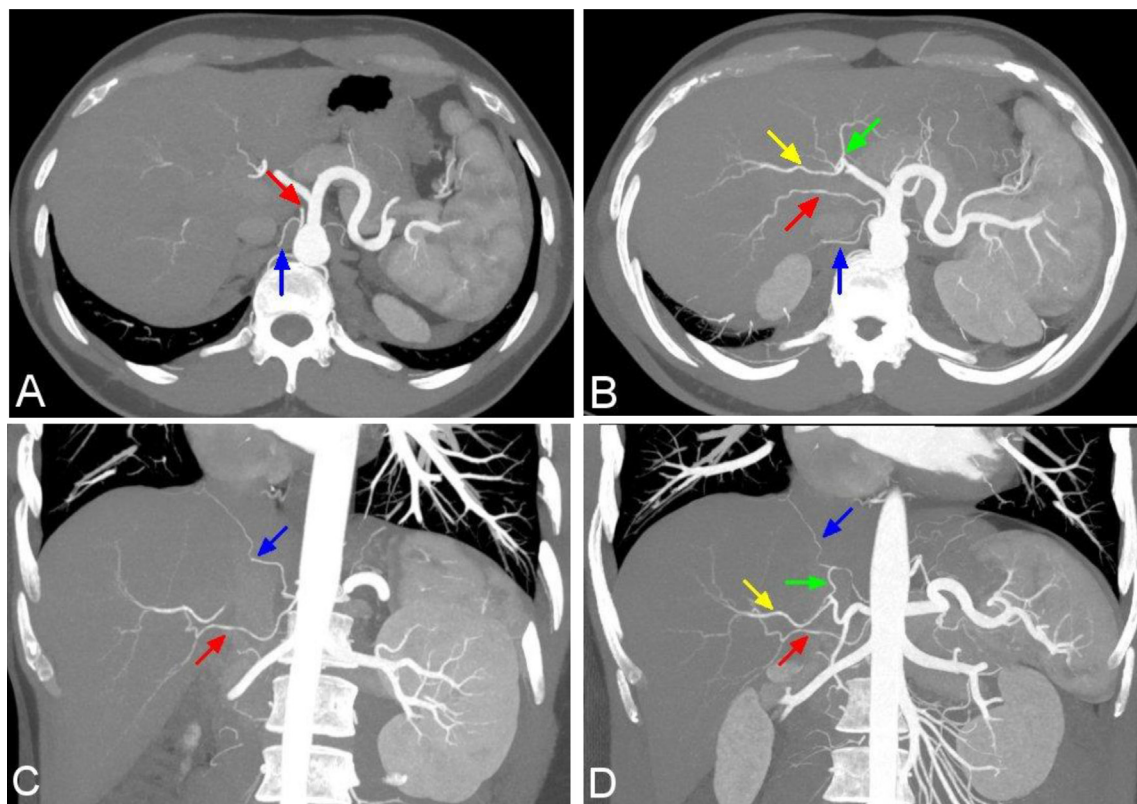
Several classifications of the anatomical variations of the common hepatic artery (CHA) have been proposed in the literature.

Michel (1966) described the hepatic arterial anatomy and its variations using the results of 200 cadaveric dissections and identified 10 types of hepatic arterial anatomy: type I: normal pattern; type II: a replaced LHA from the left gastric artery; type III: a replaced RHA from the SMA; type IV: replaced RHA and LHA; type V: an accessory LHA; type VI: an accessory RHA; type VII: accessory RHA and LHA; type VIII: a replaced RHA or LHA with other hepatic artery being an accessory one; type IX: the hepatic trunk as a branch of the SMA; and type X: the CHA from the left gastric artery [2].

Hiatt et al. (1994) modified Michels' classification into 6 categories: Hiatt Type I (normal anatomy), Hiatt Type II (LHA arising from the left gastric artery), Hiatt Type III (RHA arising from the SMA), Hiatt Type IV (any combination of a double replaced pattern), Hiatt Type V (CHA originating as a branch of the SMA), and Hiatt Type VI (an isolated aortic origin of the CHA), replacing the rare variant where the CHA arises from the left gastric artery [5].

Additional variants and patterns, not included in the classifications by Michels and Hiatt et al., were frequently encountered during surgery. This led Yan et al to develop the CRL classification which described 25 subtypes of hepatic artery based on 3-dimensional visualization of CT angiography images [6].

Wu et al 2022 found that the CRL classification is not specific for rare cases and proposed a new classification called



**Fig 1 – Axial (A and B) and Coronal (C and D) CT angiography MIP images show the left hepatic artery (green arrow) and the right hepatic artery (yellow arrow) originate from the proper hepatic artery. A right accessory hepatic artery (red arrow) arises from the right inferior phrenic artery (blue arrow).**

the extended- CRL classification, to name and classify variants that cannot be classified by the CRL classification. The ex-CRL classification is suitable for a small number of variants outside the CRL classification [7].

Right and left hepatic arteries variations have been described mainly in case reports and postmortem cadaveric evaluations. Covey et al. reported a case of replaced right hepatic artery and accessory right hepatic artery each originating from the right phrenic artery [8]. Another case of 2 accessory left hepatic arteries, one arising from the common hepatic artery and the other arising from the left inferior phrenic artery with agenesis of the right inferior phrenic artery was described by Wu et al. [7].

The above data suggest that an accessory right hepatic artery originating from the phrenic artery is an extremely rare variation. It is described as CR<sub>aOP</sub>L in the ex- CRL classification.

In orthotopic liver transplantation (OLT) the blood supply of the hepatic artery (HA) is crucial for graft survival and the prevention of biliary complications. Proper reconstruction of the HA is essential for the success of orthotopic liver transplantation (OLT). A systemic review including 19,013 patients reported that the accessory LHA and an accessory RHA were present in 3.2% and 1.6% of cases, respectively [9].

The identification and proper preservation of aberrant hepatic arteries is of great importance during vascular in-

terventional procedures and complex abdominal surgeries such as pancreaticoduodenectomy and liver transplantation, to improve the plan of reconstruction during the surgery and avoid complications including arterial hepatic ischemia, hepatic abscess and bilioenteric anastomosis breakdown [10].

Our patient was deemed unsuitable for right lobe liver donation primarily due to the presence of complex and atypical hepatic vascular anatomy identified on CT angiography. This variation would significantly complicate the surgical procedure, increasing the risk of inadequate perfusion to the donor's remaining liver and potentially complicating the implantation process for the recipient. The accessory right hepatic artery, serving as the dominant blood supply to segments VI and VII of the liver, presents a major challenge. Ensuring adequate blood supply to both the donor's liver remnant and the transplanted segment would be difficult, as preserving or reconstructing this artery during surgery is technically demanding and associated with a heightened risk of vascular complications. This atypical vascular anatomy also raises the likelihood of intraoperative bleeding, ischemia, and postoperative complications for both the donor and recipient.

The left lobe could not be used due to low expected graft-to-recipient weight ratio (GRWR) based on volume calculations.

Although the patient has no systemic or metabolic contraindications and normal liver function, the rare vascular anatomy makes the surgical procedure unsafe, leading to the decision to deem him unfit for liver donation.

## Patient consent

Informed consent was obtained from the patient for his data and images to be used in this study and published in this journal. The patients understood that their anonymity would be preserved, and no identifiable information would be disclosed.

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