Evaluation of hepatic vascular anatomy by multidetector computed tomography angiography in living liver right lobe donors

Karaciğer sağ lob canlı donör adaylarında hepatik vasküler anatominin multidedektör bilgisayarlı tomografik anjiyografi ile değerlendirilmesi

Fatma Ayça EDİS ÖZDEMİR[1], Rıza Sarper ÖKTEN[1], Mustafa ÖZDEMİR[1], Melih EREREN[1,2], Fahrettin KÜÇÜKAY[1], Muharrem TOLA[1], Eyüp ŞENOL[1,3]

Department of [1]Radiology, Türkiye Yüksek İhtisas Hospital, Ankara

Department of [2]Radiology, Ağrı State Hospital, Ağrı

Department of [3]Radiology, Aksaray State Hospital, Aksaray

Background and Aims: *The purpose of this study was to demonstrate the hepatic vascular anatomy and the variations in living right lobe donors by multidetector computed tomography angiography before the transplantation surgery and to detect the prevalence of these variations.* ***Materials and Methods:*** *Fifty-one potential liver donors (20 females, 31 males) underwent hepatic vascular computed tomography angiography in the arterial, portal and venous phases with a 16-row computed tomography scanner in our clinic. Two- and three-dimensional images were obtained using multiplanar reformat, maximum intensity projection and volume rendering techniques.* ***Results:*** *Thirty-five of the 51 patients (68,6%) had conventional arterial anatomic pattern (type I) and 16 patients (31,4%) had hepatic arterial variations. In 30 patients (58,8%), the portal vein had normal intrahepatic anatomy, while 21 patients (41,2%) had portal vein variations. Eight patients (15,7%) had normal hepatic venous anatomy and 43 patients (84,3%) had hepatic venous variations.* ***Conclusions:*** *Due to the high-speed volumetric scanning and high-quality two- and three-dimensional imaging with the use of thin slices, multidetector computed tomography angiography is a useful method for evaluating hepatic arterial, hepatic and portal venous systems in living liver right lobe donors.*

Key words: *Living liver donor, MDCT angiography, hepatic vascular anatomy*

Giriş ve Amaç: *Bu çalışmanın amacı karaciğer sağ lob canlı donör adaylarında hepatik vasküler anatomiyi ve varyasyonları multidedektör bilgisayarlı tomografik anjiyografi ile transplantasyon cerrahisi öncesinde görüntülemek ve bu varyasyonların prevalansını saptamaktır.* ***Gereç ve Yöntem:*** *Ellibir olgunun (20 kadın, 31 erkek) görüntüleri değerlendirilmiştir. Olguların tümünün incelenmesinde 16-dedektörlü multidedektör bilgisayarlı tomografi cihazı ve aynı inceleme protokolü (arteryel faz, portal faz ve venöz faz) kullanıldı. Alınan ham görüntülerden 'multiplanar reformat', 'maximum intensity projection' ve 'volum rendering' teknikleri kullanılarak iki ve üç boyutlu görüntüler oluşturuldu.* ***Bulgular:*** *Çalışma grubumuzdaki 51 hastanın 35'inde (%68,6) konvansiyonel arteryel anatomik patern (tip I) ve 16'sında (%31,4) hepatik arteryel varyasyon mevcuttu. Çalışmamıza dahil olan 51 hastanın 21'inde (%41,2) portal ven varyasyonlarına rastlanmış olup 30 hastada (%58,8) normal intrahepatik anatomi izlendi. Ellibir hastanın 43'ünde (%84,3) hepatik venöz varyasyon mevcutken 8 hastada (%15,7) normal hepatik venöz anatomi saptandı.* ***Sonuç:*** *Hızlı bir şekilde volumetrik tarama yapabilme ve ince aksiyel kesitleri kullanarak yüksek kalitede iki ve üç boyutlu görüntüler oluşturulabilme özelliği sayesinde multidedektör bilgisayarlı tomografik anjiyografi, karaciğer sağ lob canlı donörlerinin hepatik arteriyel, hepatik ve portal venöz sistemlerinin değerlendirilmesinde oldukça faydalı bir metoddur.*

Anahtar kelimeler: *Karaciğer canlı donör, multidedektör bilgisayarlı tomografi anjiyografi, hepatik vasküler anatomi*

INTRODUCTION

Preoperative scanning is essential to avoid possible surgical complications by helping to select the right donor and designing the surgery. One of the most important aims of preoperative scanning is to expose the arterial and venous vascular map (1). The liver has a complex vascular anatomy and common vascular variations (2). Some of these variations are contraindications for the transplantation while some render the surgery problematic (3). Visualization of vascular structures before the transplantation reduces the risk of the surgery and the complications (2).

Address for correspondence: Fatma Ayça EDİS ÖZDEMIR
Türkiye Yüksek İhtisas Hospital, Department of Radiology, Ankara
Phone: +90 312 306 10 00
E-mail: aycaedis@yahoo.com

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Multislice (multidetector) computed tomography (MDCT) angiography is a non-invasive method that can obtain conventional angiography-like images by volumetric scanning (4,5). Multislice CT angiography allows faster and more accurate imaging of the liver with thinner slices with a high spatial resolution (2). In addition, MDCT angiography is an appropriate method for visualization of the hepatic arterial anatomy, origin of segment IV artery, hepatic venous anatomy, and accessory hepatic vein and portal vein variations.

In this study, our aim was to demonstrate the hepatic vascular anatomy and the variations in living right lobe donors by MDCT angiography before the transplantation surgery and to detect the prevalence of the variations.

Tablo 1. Michels' classification

Type	%	Definition
I	55	Conventional anatomy
II	10	Replaced LHA originates from SGA
III	11	Replaced RHA originates from SMA
IV	1	Replaced RHA and LHA
V	8	Accessory LHA originates from SGA
VI	7	Accessory RHA originates from SMA
VII	1	Accessory RHA and LHA
VIII	2	Replaced RHA + accessory LHA or replaced LHA + accessory RHA
IX	4,5	Replaced CHA originates from SMA
X	0,5	Replaced CHA originates from SGA

SGA: Left gastric artery. LHA: Left hepatic artery. SMA: Superior mesenteric artery. RHA: Right hepatic artery. CHA: Common (main) hepatic artery.

MATERIALS AND METHODS

A total of 51 adult potential liver right lobe donors (20 females, 31 males), with an age range between 18 and 58 years (average age, 34,9 years) were evaluated for hepatic vascular anatomy and variations by a CT device with a 16-row scanner (Lightspeed Ultra, General Electric Medical Systems; Milwaukee, WI, USA) with the same scanning protocol. The scanning parameters were 8 x 1,25 mm collimation, 0,5 s gantry rotation and 140 kV. Value of mAs for each patient was modified automatically by the CT device. Scanning protocol included four phases, which were non-enhanced images, arterial phase, portal venous phase, and hepatic venous phase. No oral contrast was used. After the injection of 2 ml/kg iodine contrast material (Iodixanol, Visipaque 320 mgI/ml, General Electric Healthcare; Milwaukee, WI, USA) through an antecubital vein with an injection rate of 4 ml/s, arterial phase scanning was obtained using SmartPrep (automatic bolus-tracking program) and was started when the aortic enhancement reached the maximum amount at the level of celiac trunk. 1,25 mm slice thickness and 0,6 mm reconstruction interval were used during the arterial phase. The portal venous phase images were started 35-40 s after the beginning of arterial phase images and were obtained by using 2,5 mm slice thickness and 1 mm reconstruction interval. Hepatic venous phase images were obtained at 70-75 s with 2,5 mm slice thickness and 1 mm reconstruction interval. On a separate workstation (Advanced Workstation 4.2, General Electric Medical Systems; Milwaukee, WI, USA), two-dimensional (2D) multiplanar reformatted images and three-dimensional (3D) images with maximum intensity projection (MIP) and volume rendering (VR) techniques were obtained from thin slices of axial images. Hepatic arterial anatomy and variations were evaluated with the coronal and axial images using VR and MIP techniques and classified according to Michels' classification (6) (Table 1). In addition, the origin of the dominant segment IV artery was determined. The distance between the origin of the segment IV artery and the origin of the right hepatic artery was measured if ever the dominant segment IV artery originated from the right hepatic artery. Portal vein anatomy and variations were evaluated with axial images and VR and MIP techniques on the oblique and coronal planes based on the classification made by Koç et al. (7). In the cases of type III anatomic pattern, in which the right anterior portal vein (RAPV) and the left portal vein originated from a common trunk, the length of the common trunk was measured. Hepatic venous anatomy and variations were evaluated using axial images and on oblique-axial and axial planes using MIP and VR techniques. Presence of a vein or veins wider than 5 mm that drained segment VIII or V into the middle hepatic vein was examined. Presence of the right accessory inferior hepatic veins was examined, and the distance between the locations where the inferior right hepatic vein and the right hepatic vein drained into the inferior vena cava (IVC) was measured.

RESULTS

In our study group, 35 of the 51 patients (68,6%) had type I (conventional) arterial anatomy according to Michels' classification. Sixteen patients (31.4%) had hepatic arterial variations. Four patients (7,8%) had type III (Figure 1), 4 patients (7,8%) had type V, 3 patients (5,9%) had type VIII, 2 patients (3,9%) had type II, 2 patients (3,9%) had type IV, and 1 patient (2%) had type VII anatomic pattern. Dominant artery feeding segment IV originated from the left hepatic artery in 36 patients (70,6%),

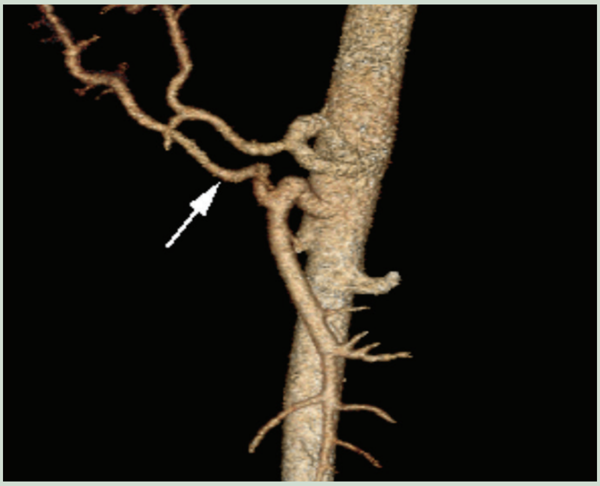

Figure 1. A 39-year-old female patient. Replaced right hepatic artery originating from SMA (type III). 3D VR image on coronal plane.

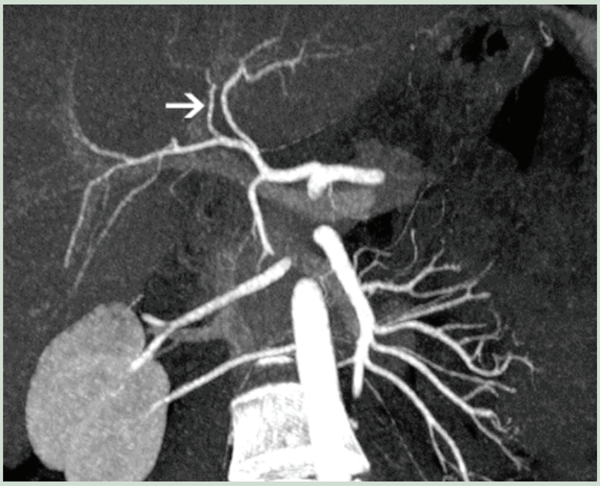

Figure 2. A 32-year-old male patient. MIP image on coronal oblique plane. Segment IV artery originated from right hepatic artery.

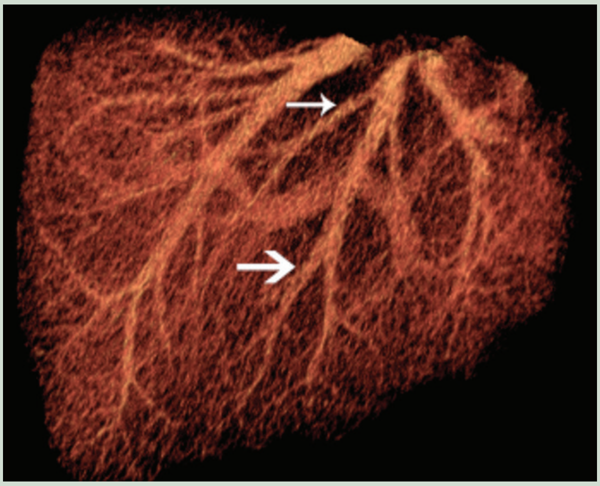

Figure 3. A 21-year-old male patient. 3D VR image demonstrates the veins draining segment VIII (thin arrow) and segment V (thick arrow) into the middle hepatic vein.

Figure 4. An 18-year-old male patient. MIP image on coronal oblique plane demonstrates the trifurcation of the right anterior portal vein, right posterior portal vein and left portal vein branches (Type II).

Figure 5. MIP image on coronal oblique plane in a 21-year-old male patient demonstrates the common trunk of the right anterior portal vein and left portal vein (Type III).

Figure 6. A 35-year-old female patient. MIP image on coronal plane demonstrates an accessory segment VIII vein originating from the right portal vein.

right hepatic artery in 15 patients (29,4%) (Figure 2), and gastroduodenal artery in 2 patients (3,9%). The distance between the origin of the segment IV artery and of the right hepatic artery was measured between 4-35 mm (average distance, 11,8 mm) in the patients whose segment IV artery originated from the right hepatic artery.

In our study group, 8 of the 51 patients (15,7%) had normal hepatic venous anatomy while 43 patients (84,3%) had hepatic venous variations. The most frequent variation found in the hepatic venous system was the accessory hepatic vein branches draining segment VIII into the middle hepatic vein (36 patients, 70,6%). Thirty-three of the 51 potential donors (64,7%) had accessory hepatic vein branches draining segment V, and 29 patients (56,9%) had accessory hepatic vein branches draining both segment V and segment VIII into the middle hepatic vein (Figure 3). Thirty patients (58,8%) had hepatic vein branches larger than 5 mm, draining segment V and/or segment VIII into the middle hepatic vein, and moved along the planned hepatectomy plane. The large vein was draining segment V in 18 patients, segment VIII in 5 patients and both segment V and segment VIII in 7 patients.

Twenty-two of the potential donors (43,1%) had right accessory inferior hepatic vein (the vein drains segment VI directly into the IVC). Nineteen of these patients (37,3%) had inferior right hepatic veins larger than 3 mm, and in 15 cases (29,4%), the distance of these veins to the IVC junction was more than 4 cm. Furthermore, 4 patients (7,8%) had 2 inferior hepatic veins.

In the normal portal vein anatomy, the main portal vein splits into the right and left portal veins in the portal hilus. The right portal vein splits into its anterior and posterior sectoral branches, and the left portal vein splits into the branches feeding segments II, III and IV. Any difference in this pattern is considered a variation. In our study group, 36 of the 51 patients (70,6%) had conventional main portal vein anatomy (type I), while 15 patients (29,4%) had main portal vein variation. Six patients (11,8%) had trifurcation (type II) (Figure 4), 8 patients (15,7%) had a common trunk of the RAPV and left portal vein (type III) (Figure 5), and 1 patient (2%) had quadrification. The length of the common trunk in the patients who had type III anatomic pattern was between 2 mm and 8.7 mm (average length, 4,9 mm).

Normal intrahepatic portal vein branching pattern was observed in 30 patients (58,8%), while 21 patients (41.,2%) had portal vein variations. Thirty-one of the 36 patients who had conventional main portal vein branching pattern also had conventional right portal vein anatomy. Five of 36 patients (13,9%) had right portal vein variation. Two patients (5,6%) had separate origin of segment VI portal vein branch from right portal vein, while 2 patients (5,6%) had separate origin of segment VII portal vein branch from the right portal vein. One patient (2,8%) had an accessory segment VIII portal vein branch that originated from the right portal vein, although that is not a previously defined variation in the literature (Figure 6).

One of the 51 patients (2%) had segmental portal vein variation traversing the interlobar boundary. In this case, a portal vein branch originating from the left portal vein traversed the interlobar boundary and fed segment VIII and segment V with its smaller branches.

DISCUSSION

Due to the development in multislice CT technology, very thin slices can be obtained as soon as possible. Due to this scanning ability provided by multislice CT, even very thin vessels can be evaluated by a non-invasive method. Arterial, portal and hepatic venous phases can be achieved in a certain timing due to the shortened imaging time. 2D and 3D images without artifacts are more qualified with the help of thinner slices.

In previous angiographic studies, the rate of accessory hepatic artery was quite variable, and was lower than the rate defined by Michels (6,8-11). This situation can be explained by the difficulty of visualizing thinner accessory vessels by angiography. The difficulty in discriminating accessory and replaced hepatic arteries by angiography can be another reason for the lower accessory artery rates. Because hepatic arterial injury may cause ischemic complications, it is essential to decide if an aberrant artery is replaced or accessory before the transplantation surgery (8). With the use of thin slices and 3D images, accessory hepatic arteries can be visualized much more easily with MDCT angiography.

Preoperative knowledge about the origin of the segment IV artery is required before right lobe or left lobe lateral segment resection. The dominant segment IV artery usually originates from the left hepatic artery. However, in some patients, it may originate from the right hepatic artery. In such a case, it is essential to clamp the right hepatic artery after it gives off the segment IV artery. Otherwise, the left lobe medial segment, which remains in the donor, will develop ischemia and the metabolic needs of the donor will not be supplied during the regeneration process (12). Thankfully, the segment IV artery or arteries can be evaluated easily before the surgery by MDCT angiography (13). In our study, 29,4% of our patients had segment IV artery originating from the right hepatic artery. In recent studies, this ratio was reported between 6-62,5% (1,14). The distance between the origin of the segment IV artery and the origin of the right hepatic artery can be measured by multislice CT angiography. This knowledge makes the dissection easier for the transplantation surgeon. According to the study performed by Guiney et al. (14), the average distance of the origin of the segment IV artery to the origin of the right hepatic artery was 1,2 cm, while Şaylısoy et al. (2) reported the average distance as 1,4 cm (4,27). In our series, the distance was 11,8 mm on average.

In the standard procedure of right lobe transplantation, the hepatectomy plane passes almost 1 cm on the right of the middle hepatic vein. It is essential to know whether an important vascular structure passes through the hepatectomy line. Veins draining segment V and/ or VIII to the middle hepatic vein that are larger than 5 mm by CT angiography must be considered before the transplantation surgery (13). If veins larger than 5 mm are detected, these veins must be reconstructed instead of clamping or the hepatectomy plane must be changed. Clamping these veins causes ischemic necrosis in the segments to which they drain, and this may cause graft failure in the recipient. We detected veins larger than 5 mm, which drained segment V and/or segment VIII to the middle hepatic vein, in 58,8% of our patients. This ratio was reported as 50% by Şaylısoy et al. (2). In our study group 35,3% of the patients had segment V vein wider than 5 mm, while 9,8% had a segment VIII vein wider than 5 mm, and 13,7% had both. Another hepatic venous variation that must be recognized before the transplantation surgery is the presence of the right accessory inferior hepatic vein. This variation is frequent and reported as often as in 68% of the patients in the literature (1,15,16). More than one accessory inferior hepatic vein can exist, and this situation may prolong the time of the transplantation surgery. An accessory inferior hepatic vein is essential for the venous drainage of the right lobe graft (13,14). If an accessory inferior hepatic vein wider than 3 mm is not reconstructed during the surgery, graft congestion and liver failure may occur due to the venous obstruction (14,15). If an accessory inferior hepatic vein wider than 3 mm exists, it is also important to know the distance between the junction of the accessory inferior hepatic vein and the right hepatic vein with the IVC. A distance of more than 4 cm makes the surgery longer and more difficult (1). In our study group, we detected inferior hepatic vein variation at a rate of 43,1%. Şaylısoy et al. (2) reported this variation as 54,9% (2). 7,8% of our patients had two right inferior hepatic veins; 37,3% of our patients had a right inferior hepatic vein larger than 3 mm. This ratio was reported as 48% by Şaylısoy et al. (2). In our study group, all of the right inferior hepatic veins with a distance to the right hepatic vein of more than 4 cm also had diameters greater than 3 mm (29,4%).

Most of the studies reported the trifurcation (type II) as the most common portal vein variation, while we most frequently detected the trunk of the RAPV-left portal vein (type III) variation (15,7%) (1,14,17,18). This difference can be a result of using different methods while imaging the ramification of the portal vein. In the cases where thicker axial slices are obtained, a short trunk of the RAPV and left portal vein can easily be misdiagnosed as trifurcation. In such cases, 3D images are very helpful in demonstrating the anatomy. Like our study, Atasoy et al. (19) also reported type III portal vein anatomy as the most common variation of the main portal vein in the study made in 200 patients with MDCT.

Discrimination of type III portal vein anatomy from type II portal vein anatomy has some advantages. Because of the closer origins of the right anterior and posterior veins of the donors who have type II portal vein anatomy, a single portal lumen can be obtained during the surgery despite the absence of a right portal vein. On the other hand, type III anatomy makes surgery more complicated, because two transections of the RAPV and right posterior portal vein (RPPV) are needed, and two portal lumens in the right lobe graft must be obtained (20). The length of the common RAPV-left portal vein trunk is also important during the surgery. When the common trunk is short, RPPV of the donor is anastomosed to the right portal vein of the recipient, and the RAPV of the donor is anastomosed to the left portal vein of the recipient. This kind of Y-graft allows simultaneous reperfusion in both of the portal vein branches of the donor. When the common trunk is long and consequently the donor veins are wide apart, an extension type graft is needed for reconstruction of the donor RAPV branch. This situation can cause delayed reperfusion of a segment of the graft (21). There is not a cut-off value for the length of the common trunk in the literature above which an extension graft is needed. The average length of the RAPV-left portal vein trunk was 4,9 mm in our study, while Atasoy et al. (19) reported this as 7,9 mm.

Right portal vein variations were reported as 33,5% in a recent cadaveric study, although they are not as common in the radiology literature (22). Preoperative evaluation of the right portal vein variations is of value in segmental resection of the right lobe and in right posterior segment transplantation. In our study, we detected right portal vein variation in 5 of 36 patients (13,9%). This ratio was similar in the study made by Atasoy et al. (19) by MDCT (16,8%), while Koç et al. (17) reported the same ratio as 3,9% in their study, also made by MDCT. This significant difference proves the importance of using smaller collimation and reconstruction interval in demonstrating thinner portal vein branches.

Due to the high-speed volumetric scanning and high-quality 2D and 3D imaging with the use of thin slices, multislice CT angiography is a very useful method for evaluating hepatic arterial, hepatic and portal venous systems of living liver right lobe donors.

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