Role of MDCT angiography in assessment of vascular variant in potential living liver donor transplantation

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Abstract Purpose: This study intends to assess the impact of multiphase three-dimensional Multi-detector Computed tomography (MDCT) angiography in facilitating patient selection and surgical planning in potential donors being evaluated for living adult right lobe liver transplantation. 
Patient and methods: Fifty consecutive potential living liver donors who underwent three-dimensional (MDCT) angiography were included. MDCT angiography findings were compared with surgical results.
Results: The overall impact of three-dimensional MDCT angiography in diagnosis of A.
Conclusion: MDCT angiography with multiplanar and three-dimensional techniques is a valuable tool for the evaluation of potential living liver donors that provides complete and comprehensive information on the hepatic vascular anatomy. It allows an optimal graft to be obtained that maintains the balance between blood supply and venous drainage.

1. Introduction

Since the 1980s, adult donors have successfully donated portions of their left lobes to pediatric patients needing transplantation. Recent improvements in surgical techniques have permitted the safe performance of right lobe hepatectomy for transplantation, thereby allowing adults awaiting transplants to also benefit from generous living donors (1). However, given the far greater complexity of right hepatectomy, safe harvesting and successful transplantation require especially careful selection of donors and accurate preoperative planning (2). Imaging findings that can disqualify a donor candidate include parenchymal disease and certain vascular and biliary
anomalies in an upset of these individuals. Unsuspected parenchymal abnormalities such as liver steatosis or insufficient liver volume, either in terms of transplanted tissue for the recipient or residual tissue for the donor may be reasons for exclusion as donors (3). Overall, automated liver volumetry based on multiphase CT acquisitions is feasible and more rapid than manual segmentation (4). Several common anatomic variants, such as anomalous origin of the left portal vein from the right anterior portal vein can substantially increase the complexity of the surgical procedure and therefore considered reasons for exclusion (5). Other anatomical variations which prohibit living donation are, e.g. absence of the main portal vein bifurcation or severe biliary or arterial malformations (6). Preoperative identification of anomalous vascular anatomy not only can help the surgeons decide which donors are suitable candidates, but also, in those with favorable anatomy, can guide the safe harvesting of the right lobe from the donor and its transplantation to the recipient (7). Multidetector CT is a technologic advance that permits high-speed and high-resolution helical imaging of the entire liver volume during a single breath-hold. Rapid helical data acquisition has resulted in increased body coverage, decreased motion artifact, better use of contrast bolus, and multiphase organ scanning that allows accurate vascular mapping. The combination of fast helical scanning and image processing in three-dimensional (3D) and multiplanar reconstructions has resulted in a dramatic improvement of image quality and the ability to depict fine anatomic-vascular details (3). Triphasic dynamic CT studies with dual-arterial Phase. The first arterial dominant phase was used to reconstruct the hepatic arteries in different planes of thick slab maximum intensity projection mainly the axial, coronal and coronal oblique planes. The second portal dominant phase was used to reconstruct the portal venous system without any contamination by the systemic hepatic veins also in different planes of thick slab maximum intensity projection mainly the axial, coronal and coronal oblique planes. The third venous phase was used to reconstruct the systemic hepatic veins also like the two previous phases in M1P (8).

2. Patient and methods

This study included 50 consecutive potential living donors, 28 females and 22 males. Their age ranged from 21 years to 51 years with a mean age of 27.4 ± 4.6 years. All cases underwent evaluation with the three-phase dual-enhancement multi-detector row CT protocol. The study was conducted in National liver institute Monofya university in accordance with the guidelines of the local ethics committee. Written informed consent was obtained from all patients. Prior to Multidetector Computed Tomography (MDCT) examination, relevant clinical data, Laboratory: blood group, complete blood culture (CBC), erythrocyturation rate (ESR), Liver function tests, renal function tests, serum cholesterol, prothrombin time, bleeding time and viral hepatitis and Grey scale US and color Doppler examination of the liver were obtained in every living donor. CT evaluation: All the 50 potential donors were examined by multidetector row CT angiography with reconstruction of different hepatic vessels (arteries, veins and portal vein). All the 50 potential donors were chosen after succeeding the four step protocol of evaluation and they were considered potential right lobe graft donors. From the operating team we got the intra operative right lobe graft vascular anatomy of the liver.

3. Technique of multiphase MDCT

CT scans were acquired with 16 channel detector row CT scanner (Emotion; Siemens medical system, Germany). All donors were instructed to fast for 6–8 h prior to examination. They were asked to continue adequate simple water intake up to 3 h prior to examination to ensure adequate hydration and to fill the stomach and bowel by water to help proper subtraction techniques and visualization of the target vessels. Evacuation of the urinary bladder was done before the procedure. Donors were taught how to hold breath during examination when requested, to ensure their cooperation. Donors were positioned supine on the CT table in the “Head first” position with his arms resting comfortably above the head. An 18–20 gauge catheter was placed into a superficial vein within the ante-cubital fossa. Before the contrast material was administered by the injector, saline injections were manually administered at a high rate of flow, with the donor’s arms in the scanning position. This was done to ensure the successful cannulation of the vein and absence of leakage. One scout was acquired in antero–posterior view. The examination is planned on these scouts from the level of the top of the right diaphragmatic copula (hepatic dome) till 20 cm caudally in precontrast and post contrast sequences. The pre-contrast series is taken by using a 10 mm nominal section thickness, a slice pitch of 6, a gantry rotation period 0.6 s, and a table speed of 15 mm per rotation. X-ray tube voltage was 120 kV, and the current was 280–300 mA. The timing of injection is determined by computer automated scanner technology (bolus tracking) where the region of interest is positioned just above the celiac axis and the threshold of contrast concentration is fixed at 120–150 HU. The post-contrast series following the injection of contrast medium using an automatic pump with a volume that ranges between 120 and 150 ml according to the donor’s weight (1.5–2 ml/kg) at a flow rate 4–5 ml/s. The contrast medium used was low osmolar non-ionic contrast medium (Ultravist 370 mg). Helical CT was performed by using a 2.5 mm nominal section thickness, a slice pitch of 6, a gantry rotation period 0.6 s, and a table speed of 15 mm per rotation. Patients were requested to hold their breath during the precontrast phase and the four phases of acquisition for about 8–10 s each and were allowed to breathe quietly after that. The arterial dominant phase starts about 18–20 s post-injection till the end of the 20 cm distance then after a delay of 8 s the portal dominant phase is started similarly as the 1st one (about 40 s post-injection). Then the 3rd phases (venous phase) are started after a delay of 10 s from the end of the 2nd phase to end the whole examination. Sections were reconstructed at 2.5 mm which is the nominal section thickness. The whole examination took 68 s. All images were transferred to the workstation for reconstruction of the hepatic vasculature. The 1st phase of contrast injection is used to delineate the arterial including the celiac and superior mesenteric vessels especially the hepatic artery and its intra hepatic branches. Then the second phase of contrast was used to visualize the portal venous system including the splenic, superior mesenteric and main portal vein and its intra hepatic branches. The last phase is used to visualize...
The IVC and the intra-hepatic veins. Three dimensional maximum intensity projections (MIP), volume rendering (VR.), curved planer reformations were created at different angles of views mostly antero–posterior, both obliques, and lateral with zooming on areas of abnormal findings.

4. Result

In our study the vascular variant in potential living liver donors were classified into hepatic artery (HA), portal vein (PV) and hepatic veins variants. All vascular variants in studied patients were reliably evaluated by multiphase multiplanar and three-dimensional MDCT angiography images. MDCT findings were compared with surgical results. The overall impact of three-dimensional MDCT angiography in diagnosis of vascular variant in potential living donors was 100%. The classic anatomy of main hepatic artery originating from the celiac trunk is seen in 35 cases (70%), while RHA originating from SMA in eight cases (16%), CHA originating from SMA in four cases (8%), RHA from the aorta in two cases (4%) and two LHAs in one case (2%) (Table 1). Variation in portal venous anatomy occurred in 20% of patients and includes nine patients with trifurcation of the portal vein (18%) and one patient posterior right portal vein from main portal vein (2%) (Table 2). Hepatic venous variants were present in 45 patients (90%) with classic anatomy, in three patients (6%) as early confluence to the right and accessory inferior right hepatic vein was detected in two patients (4%). Some patients show insignificant (less than 3 mm) few accessory veins draining into IVC (Table 3).

5. Discussion

Liver transplantation was introduced in 1968. It is the treatment of choice for patients suffering from end-stage liver disease. Over the years, surgical refinements, greater clinical expertise, and more effective immunosuppressant have contributed greatly to the improved technical success of this operation (11). The shortage of cadaveric livers and the increasing demand for liver transplantation have prompted a search for an alternative to cadaveric transplantation. Right lobe living donor liver transplantation may provide such an alternative. Right lobe living donor liver transplantation is a technically challenging procedure that entails resection of the right hepatic lobe from a suitable donor and transplantation of the right lobe in a recipient after the removal of the recipient’s native liver. Before transplantation, potential donors undergo extensive evaluation with the intent of minimizing complications in the healthy donor and optimizing graft function in the recipient (12). MDCT is a technologic advance that permits high-speed and high-resolution helical imaging of the entire liver volume during a single breath-hold. Rapid helical data acquisition has resulted in increased body coverage, decreased motion artifact, better use of contrast bolus, and multiphase organ scanning that allows accurate vascular mapping. The combination of fast helical scanning and image processing in three-dimensional (3D) and multiplanar reconstructions has resulted in a dramatic improvement of image quality and the ability to depict fine anatomic-vascular detail (3). Multi-phasic and multi-planar capabilities, representing the added value of any MDCT scanner, starting with 4-slice, have been further improved: shortening of scanning time to a few seconds offers optimal separation of different vascular phases, this improving lesion detection and characterization; z-axis resolution of 0.3–0.6 mm makes CT a true isotropic imaging modality, with the acquired volume perfectly suitable for multi-planar reconstructions and accurate organ and lesion volumetry. Finally, the large volumetric coverage per rotation (40 mm) opens the era of functional imaging, represented by liver perfusion, with exciting possibilities offered in terms of earlier diagnosis, lesion characterization and assessment of therapy response to be discovered in the next few years (13). The Multislice CT is considered a new advance in the field of diagnostic radiology and an important tool for investigating and imaging the liver. There are three advantages of Multidetector CT; (1) Imaging is
extremely rapid, hepatic scanning can be completed during the interval of peak hepatic contrast enhancement. (2) CT of the liver can be performed routinely with very thin collimation; yielding greater conspicuity of small lesions for better detection of lesions. (3) Respiratory misregistration between adjacent scan slices is eliminated. These three factors combine to result in improved lesion detection in the liver. In addition, multidetector CT permits dynamic subtraction CT of the liver during a single breath hold (14). Assessment of the hepatic arterial anatomy is one of the most important steps in the preoperative evaluation of potential liver donors because hepatic arterial anatomy is extremely variable and some anatomic variations may necessitate modification of the surgical approach. The main goal of presurgical evaluation of the hepatic arterial anatomy is to provide a complete arterial “road map” for the transplantation surgeons (11). In 2001, Jones R.M. and Hardy K.J. made a study on 180 livers harvested from multi-organ donors to document the anatomy of the hepatic artery with the purpose of reminding surgeons of the need for this essential knowledge in order to practice safe hepato-biliary surgery. They resulted that the left hepatic artery had its origin from the common hepatic artery trunk in 144 instances (80%), arose from the left gastric artery in 15% either the splenic artery (2%), gastroduodenal artery (1%) or the aorta, celiac axis and superior mesenteric artery in 1% of cases. The right hepatic artery took origin from the main trunk of the common hepatic artery in 135 instances (75%), arose from the superior mesenteric artery in 18%, the gastroduodenal in 6%, right gastric artery or aorta in 2% of cases. There was a major variation of the celiac axis in 8% of cases studied. The celiac axis and the superior mesenteric artery had a common origin in three instances (2%), and the celiac axis was absent in two (1%), with the common hepatic, splenic and left gastric arising from the aorta. A number of other abnormalities were observed: the celiac axis arising from the superior mesenteric artery, the common hepatic from the superior mesenteric with the splenic and

Fig. 1  Drawings showing anatomic variation of RT portal vein branching (type A, type B, type C, type D and type E). Right (R) and left (L) branches; anterior (A) and posterior (P) branches; P4, P5, and P8, portal venous branches to segments 4, 5, and 8, respectively; F, falciform ligament. (9).

Fig. 2  Drawings show anatomic variations of intrahepatic portions of hepatic veins (10).
left gastric vessels arising from the aorta. The left gastric artery arose from the splenic in two instances (1%) and the aorta in one (0.5%), and the gastroduodenal artery arises from the celiac axis and from the right hepatic artery in one instance (0.5%), respectively. In 103 consecutive dissections, the middle hepatic artery arises from the right or left hepatic arteries in 82 instances (80%), the gastroduodenal in nine (9%), the superior mesenteric and splenic in two instances each (2%), the left gastric and common hepatic arteries in one instance each (1%) and was not identified in six dissections (6%). Over all there was an abnormality in 43% of dissections: 48% were multiple

Fig. 3 A 26 year old male donor with classic vascular anatomy.

7% had more than two vascular variations (15). Knowledge of the normal anatomy, most frequent variants and congenital and acquired anomalies of the portal venous system is of great importance for liver surgery. Among the most common branching variants of the portal vein are trifurcation, right anterior portal branch arising from the left portal vein, and right posterior portal branch arising from the main portal vein. Agenesis of the right or left portal vein is the most frequently reported congenital anomaly. Venous collateral vessels due to portal hypertension and cavernous transformation of the portal vein are best evaluated with cross-sectional imaging.

Fig. 4 A 19 year old male donor with arterial and venous vascular variants.

Fig. 5 A 22 year old male donor with portal and venous vascular variants.

Fig. 6 A 25 year old male donor with hepatic artery and venous vascular variants.
Intrahepatic portosystemic, arterioporal, and arteriosystemic fistulas and associated perfusion anomalies have characteristic features at dual-phase helical CT (16). Type B portal vein is anastomosed in an end-to-end fashion to the recipient portal trunk. Dual anastomosis to the bifurcation of the recipient portal vein is used in type B cases and type C cases. In extremely rare cases of type E, graft P8 is finally sacrificed. A venous graft is interposed for the reconstruction of P5 (9). Schroeder et al. has found that bifurcation of the main portal vein into left and right portal veins, was seen in 195 patients (type A: 78.6%). In 53 subjects (21.4%), anatomic variants were revealed, which included trifurcation of the main portal vein (type B: n = 38, 15.3%), right anterior portal vein draining from the left portal vein (type C: n = 10, 4.0%), left portal vein originating from the right anterior portal vein (type D: n = 3, 1.2%), and right anterior portal vein deriving from the main portal vein (type E: n = 2, 0.8%). (16). Schroeder et al. has stated that in 248 examined candidates, the hepatic venous system was accurately demonstrated. According to the classification of the right hepatic drainage pattern by Nakamura and Tsuzuki, type 1 drainage was seen in 140 patients (56.5%), which included a large right hepatic vein draining an extensive area of the right lateral sector and part of the right paramedian sector. In 71 candidates (28.6%), type 2 hepatic venous drainage was present, which included at least one thick inferior right hepatic vein draining directly into the inferior vena cava. In 37 subjects (14.9%), findings at CT angiography revealed type 3 drainage, which included right lobe drainage allocated to a short right hepatic vein, a large-sized middle hepatic vein, and an inferior right hepatic vein (17) (See Table 4 and Figs. 1–6).

6. Conclusion

Multidetector CT is a valuable tool in the evaluation of potential living liver donors that provides complete and comprehensive information on the hepatic vascular anatomy. It contributes to donor safety, highest priority during the selection process, surgical planning-and allows an optimal graft to be obtained that maintains the balance between blood supply and venous drainage.

Conflict of interest

The authors have no conflict of interest to declare.

References