3DCT Angiography for Detection of Vascular Complications in Pediatric Liver Transplantation

Yu Fan Cheng,[1,2] Chao Long Chen,[3] Tung Liang Huang,[1] Tai Yi Chen,[1] Yaw Sen Chen,[3] Chih Chi Wang,[3] Leo Leung-chit Tsang,[1] King Wah Chiu,[4] Bruno Jawan,[5] and Hock Liew Eng[6]

Catheter angiography for early diagnosis of vascular complications in pediatric liver transplant yields excellent results but remains an extremely invasive examination for younger children, precluding its routine use. We assessed the efficacy of three-dimensional multislice computed tomographic angiography (3DCTA) as an alternative option in these patients. *Methods* Twenty children suspected of vascular complications on clinical grounds, laboratory findings, or Doppler ultrasound underwent 3DCTA between April 2000 and April 2003. Interventional procedures via conventional angiography were subsequently performed in 5 cases, thrombolytic therapy in 4, surgical in 1, and conservative treatment in 10. *Results* Two hepatic artery stenosis,1 hepatic artery thrombosis, 5 hepatic vein stenosis, 4 portal vein occlusion, 1 portal vein stenosis, and 7 non-vascular lesions were detected, all of which paralleled the findings of catheter angiography, Doppler ultrasound, and operations. The diagnostic accuracy for vascular complication was 90%. The sensitivity and specificity were 86.7% and 100%, respectively. The positive and negative predictive values were 100% and 71.4%, respectively. To date 19 patients are alive, with a median follow-up period of 24.8 months. In conclusion, 3DCTA is accurate and efficient in the identification of pathological vascular insults and offers essential information for major decision on further management of the vascular complications in pediatric recipients of liver transplant. (*Liver Transpl 2004;10:248–252.*)

Abbreviations: 3DCTA, three-dimensional multislice computed tomographic angiography.

From the [1]Department of Diagnostic Radiology and Liver Transplant Program, [2]Department of Diagnostic Radiology, [3]Department of Surgery, [4]Department of Hepatogastroenterology, [5]Department of Anesthesiology, and [6]Department of Pathology, Chang Gung University, Chang Gung Memorial Hospital, Kaohsiung Medical Center, Kaohsiung 83305, Taiwan.

Supported by project grant NRHI-GT-EX92-9228SP from the National Health Research Institutes and NSC 91-234-182A-1681 and NSC92-2314-B-182A-041 from the National Science Council, Taiwan.

Address reprint requests to Yu Fan Cheng, MD, Department of Diagnostic Radiology, Chang Gung Memorial Hospital, 123 Tai-Pei Road, Niao-Sung, Kaohsiung 83305, Taiwan. Telephone: 886-7-7317123 (ext. 3027); E-mail: cheng.yufan@msa.hinet.net.

Published online in Wiley InterScience (www.interscience.wiley.com).
DOI 10.1002/lt.20055

Liver transplantation has become an important treatment option in the management of end-stage liver disease. The combination of recent improvements in operative technique, immunosuppressive therapy, and organ utilization has resulted in better post-transplant outcome. However, vascular complications contribute to significant causes of morbidity and mortality, especially in pediatric cases. The incidence of hepatic artery thrombosis is reported to be 4% in adult cases, 12% in pediatric cases, and 30% in children younger than 1 year old, in which age group re-transplantation is most commonly indicated.[1,2,3] Complications associated with the hepatic and portal veins are less common compared to those that arise from the hepatic artery.[2,4] Intraoperative Doppler ultrasound (US) has greatly facilitated early detection of vascular problems that could be remedied on the spot. Routine postoperative evaluation of the integrity of the graft vasculature via Doppler US is highly sensitive and specific for vascular insults, but extensive bowel gas and fluid collection and an irritable young child could deter thorough study.[5] Catheter angiography remains the standard assessment of vascular insults, but its invasiveness and higher failure rate, especially in pediatric patients, prompted the consideration of other alternatives. Detail blood supply of the liver in both donor and recipients for liver transplant using multislice computed tomography that allows rapid imaging of the entire upper abdomen with high resolution incorporated with three- dimensional and multiplanar reconstructions has been demonstrated.[6,7] Our study evaluates the application of this modality for the perfect imaging diagnosis of vascular complication of the pediatric patients after liver transplant in a rapid and safe environment, even in critical condition.

Methods and Materials

Ten boys and 10 girls, with an age of 2.0±2.3 years (mean±SD range, 0.58–10) and weight of 10.60±6.06 kg (mean±SD range, 5.6–32), who had underlying disease of biliary atresia (n=16), glycogen storage disease (n=1), hepatitis B liver cirrhosis (n=2), and fulminant hepatitis (n=1), underwent living donor and split graft liver transplant with

Table 1. Summary of Characteristics of the Recipients

	Number of cases	Mean ± SD	Range
Recipients			
Age (years)	20	2.0 ± 2.3	0.6–10
Gender (Male/Female)	10/10		
Body weight (kg)	20	10.6 ± 6.1	5.6–32
Underlying disease			
Biliary atresia	16		
Glycogen storage disease	1		
Hepatitis B liver cirrhosis	2		
Fulminant hepatitis	1		
Graft weight recipient ratio	20	3.0 ± 1.1	1.1–5.1

graft weight recipient ratio of 3.03±1.11 (mean±SD range, 1.1–5.12) (Table 1). Multislice contrast-enhanced CT angiography was performed between April 2000 and April 2003 if biliary and vascular complication was suggestive on Doppler US, elevated serum liver enzyme, abnormal clinical presentation, or pathology findings. Correlated Doppler ultrasound findings were obtained in 20 patients, catheter angiography in 6, and surgical intervention in 1.

3DCT Angiography

Three-dimensional multislice computed tomographic angiography (3DCTA) was performed as follows. Contrast-enhanced multislice CT angiography was performed with a Somatom Volume Zone scanner (Siemens AG, Germany). All patients were anesthetized with intravenous propofal (0.5–1mg/kg) without tracheal intubation. Ioversol (Optiray 320; Mallinckrodt Medial, St Louis, Mo.) 1.5ml/ Kg was injected via a 20-gauge IV angiocatheter at 1mL/sec. Scanning was delayed for 8–10 seconds, determined by the peak interval for aortic enhancement, to capture the arterial phase of the bolus contrast material. The scanning parameters for the first scan acquisition were: high-speed mode with pitch of 5:1, table speed of 12 mm, slice thickness of 1.25 mm with 1.25 mm interval, tube voltage of 120 KV at a current of 130 mAs. The 1.25×1.25mm data set was reconstructed to 0.9×0.9 mm for 3D reconstructions. The second acquisition was performed using the same parameters within the 40 seconds the contrast was injected. All 3D images were constructed by the radiologist (Cheng, YF), who took 10 minutes for each set. Detailed 3-dimensional images of the celiac artery, superior mesenteric artery, portal vein, and inferior vena cava were obtained for thorough assessment using multiple plane reconstruction and maximum-intensity projection. The 3DCTA was interpreted by one radiologist at the workstation after viewing the raw data and the reformatted images in projection views and axial imaging. Stenosis was defined as severe (>75%), moderate (>50%), or mild (<50%). Other nonvascular complications such as fluid collection, bile duct dilatation, liver infarcts, abscess, or biloma were also recorded.

Doppler Ultrasound

Doppler US studies were performed daily after liver transplant for 2 weeks and then as required during follow-up using the Acuson 128 scanner (Acuson, Mountain View, Calif.) with 7.0 or 4.0 MHZ transducer in the imaging and Doppler mode. Doppler US waveform, peak systolic velocity, and pulsatility index of the hepatic artery were recorded at the hepatic hilum and umbilical portion for whole liver graft and partial liver graft, respectively. Doppler US waveforms with an angle-corrected flow velocity of the hepatic veins were recorded at 1 and 3 cm apart from the inferior vena cava, while that of the portal vein at the cross-sectional area at the main portal vein and the transverse portion of the left portal vein were recorded for whole liver graft and partial liver graft, respectively.

Results

3DCTA successfully performed in these 20 patients revealed hepatic artery stenosis (n=2), hepatic artery thrombosis (n=1), hepatic venous stenosis (n=5), portal vein narrowing (n=1), portal vein occlusion (n=4), and non-vascular lesions (n=7).

Hepatic Artery Complications

Total occlusion of the hepatic artery was found in an asymptomatic 1-year-old infant on the second day after living donor liver transplant. Routine Doppler US study revealed absence of intrahepatic artery signal and 3DCTA showed non-enhanced artery in the liver graft with interruption of the hepatic artery at the anastomosis (Fig 1). Immediate re-operation confirmed complete occlusion at the origin of donor hepatic artery. The

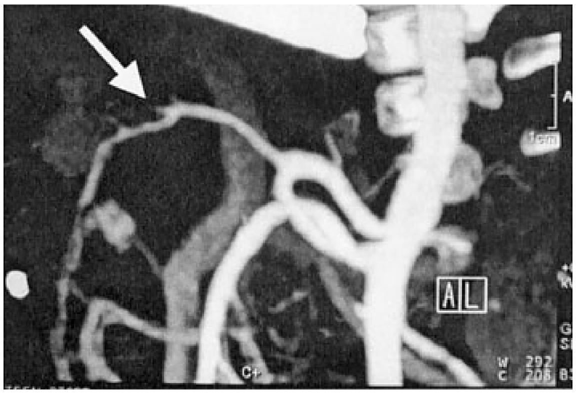

Figure 1. CT angiography shows complete occlusion of the hepatic artery (white arrow; ⇧) at the anastomosis.

graft was secured after thrombolectomy with re-anastomosis.

Hepatic Vein Stenosis

Five patients suspected of hepatic vein stenosis due to prolonged ascites showed flattened waveform and decreased velocity of the hepatic vein on Doppler US. The degree of stenosis was well demonstrated on the 3DCTA (Fig. 2A) and confirmed by trans-jugular hepatic venography where subsequent interventional angioplasty or stent insertion was performed (Fig. 2B). The follow-up 3DCTA revealed patent hepatic vein.

Portal Vein Complications

Five patients were suspected of post-transplant portal vein stenosis due to diminished intrahepatic portal flow on Doppler US a few months after transplant. 3DCTA provided detailed information on the site and extension of stenosis, occlusion, collateral circulation, and varices in all 5 cases. Four were diagnosed with total occlusion of the portal vein at the anastomosis (Fig. 3) and required recombinant tissue plasminogen activator for systemic thrombolytic therapy, while one portal vein stenosis (<50%) without any symptom was not treated.

Clinical Suspicions of Vascular Complications

Elevated liver function enzyme (n=5), sepsis (n=1), and biliary complication (n=1) raised suspicion in 7 patients. All 7 cases had patent hepatic artery on 3DCTA. Two had intrahepatic hepatic artery insults with focal liver graft infarction suggested only on axial view, which was later confirmed by pathological biopsy.

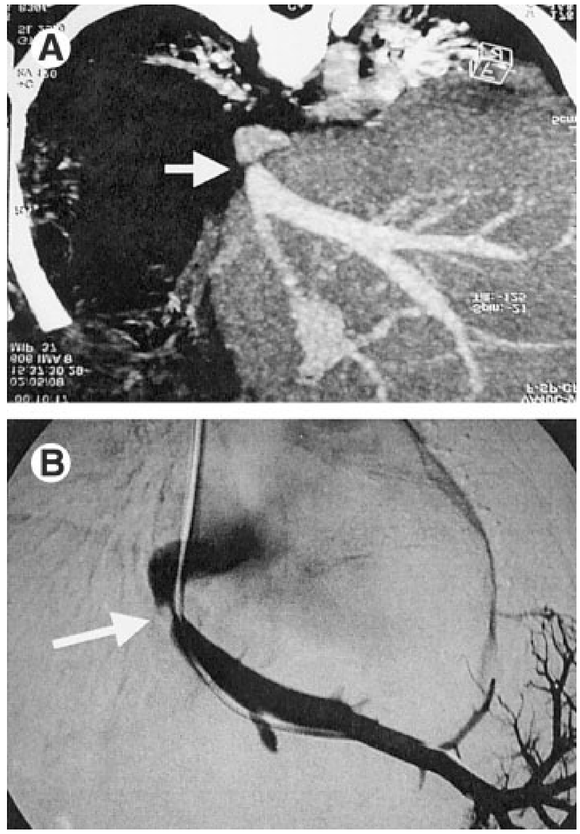

Figure 2. (A) CT angiography shows stenosis of the hepatic vein at the anastomosis (white arrow; ⇧). (2B) Transjugular hepatic venography shows stenosis of the hepatic vein at the anastomosis (white arrow; ⇧) similar to the CT angiographic picture.

Thus, the condition was underestimated by 3DCTA. The patients recovered after conservative treatment. The other 5 cases had associated findings of multiple liver microabscess (n=1), normal anatomical finding

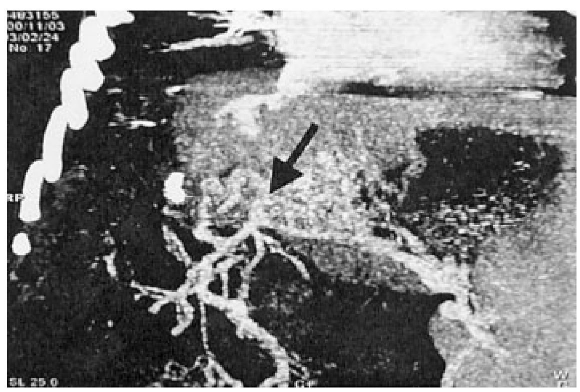

Figure 3. CT angiography shows complete occlusion of the portal vein (black arrow; ↑) with cavernous transformation at the hepatic hilar region.

(n=3), and primary nonfunction liver with diffuse liver infarct (n=1). They were all confirmed by Doppler US, clinical follow-up, and medical treatment. One 1-year-old patient died 9 days after transplant due to primary nonfunctioning graft, surgically proven as a graft with 90% infarction.

The diagnostic accuracy of vascular complication by 3DCTA was 90% (18 of 20 cases). The sensitivity and specificity were 86.7% (13 of 15) and 100% (5 of 5), respectively; the positive and negative predictive values were 100% (13 of 13) and 71.4% (5 of 7), respectively. Nineteen patients are alive to date after a median follow-up of 24.8 months.

Discussion

Multislice 3DCTA has been employed in both pretransplant evaluations in potential pediatric recipients of living donor liver transplant and detection of vascular complication in adults after liver transplant in our series as previously reported.[8] We have expanded this application on pediatric recipients for detection of vascular complication after liver transplant. Hepatic artery thrombosis is the most common cause of early graft failure that usually necessitates re-transplantation.[9] Microsurgical technique was used for all hepatic artery anastomosis for both full-sized and partial grafts in our series and only 2 hepatic artery complications were encountered. Re-anastomosis and interventional thrombolysis was performed for each case, respectively, without graft loss or mortality.[10]

Acute and late-onset portal vein thrombosis, the former a life-threatening complication immediately after transplant and the latter a well-tolerable condition, contribute to significant morbidity such as portal hypertension or hepatic ischemia that require intensive therapy.[2,13] Even though routine intraoperative Doppler US had greatly facilitated the detection and management of vascular problems on the spot, postoperative venous insults in partial liver graft recipients, especially those with pathological native portal vein, were still encountered in our series. The course of the portal circulation, particularly at the cavernous transformation, was undetectable by Doppler US in the 4 cases with late-onset portal vein thrombosis presented with repeated variceal bleeding. Non-invasive 3DCTA is superior to Doppler US to detect the location of the vascular complications. It is also more reliable than conventional angiography in accurate documentation of the incidence of recanalization of the portosystemic shunt, development of collateral veins, dissolution of thrombi, and the degree of recanalization of the main trunk of the portal vein. Thus 3DCTA has a role for prompt diagnosis and safe monitoring throughout the course of treatment.

Impairment of graft function due to hepatic vein stenosis occurs only in severely compromised conditions.[14] The presence of massive and prolonged ascites with monophasic waveform of low velocity on Doppler US of the hepatic vein is suggestive, but the extent of the lower limit is controversial.[5] 3DCTA in our study has achieved a high accuracy, sensitivity, and specificity for the diagnosis of hepatic vein stenosis, correlated well with the angiographic findings of a pressure gradient across the anastomosis. Moreover, 3DCTA provides essential information for satisfactory intervention of this complication. The choice of treatment, usually balloon dilatation via transjugular venous approach, requires precise diameter and opening direction of the orifice for catheter and stent selection to accommodate appropriate size and length of the balloon for smooth catheterization of the stenotic intrahepatic vein.[15] Three-dimensional depictions of the actual size and site of the hepatic venous opening meet the interventional radiologist's needs in this challenging task.

Liver ischemia or infarction, mostly involving the hepatic artery but occasionally involving the portal vein, is identified as a non-enhanced wedge-shaped lesion on conventional CT.[12] Two cases of focal liver infarct were recognized in our series as a non-enhanced wedged-shape area on the axial view but not on the reconstructed images due to the small caliber of the intrahepatic artery. The large-sized graft, with a graft weight recipient ratio greater than 3, in the relatively small abdominal cavity that already contained the often enlarged spleen, suffered from mass effect directed from the abdominal wall and left upper quadrant, thus resulting in focal liver infarct at the peripheral of the left lateral segment.

Even though Doppler US has been routinely used as a noninvasive modality for follow-up of vascular insult after liver transplant, thorough study relies on the technically experienced operator and the condition of the patient. Poor or non-visualization of the vascular structure would occur if it were located deep in the organ, superimposed by abnormal gas, or performed on an irritable child. Extensive collateral circulation and massive liver parenchymal necrosis or even systemic hypotension would result in false negative and positive findings, respectively.[11] Hepatic catheter angiography for the assessment of vascular insults has been the gold standard but the procedure is not without risks or complications, especially in young children. 3DCTA provides sufficient information not only on patency or stenosis of smaller vessels but also on other abnormalities in the liver parenchyma, biliary, and extrahepatic sites, which forms the major decision for the treatment of the detected vascular complication. In our series, 3DCTA findings of 6 cases were well correlated with catheter angiography and operation, while the rest were correlated with Doppler US, biopsy, or subsequent thrombolytic therapy and other medical treatment, of which all showed high accuracy. 3DCTA, with its excellent spatial resolution and faster scanning time to provide multislice imaging using only intravenous propofal for sedation, is a simpler method, even for pediatric patients.

The scanning time from the arterial to venous phase in our series is completed within 60 seconds. Radiation exposure to the patients and operators was reduced, while less contrast medium (1.5cc/kg) was needed. The increased speed of data acquisition allowed marked vascular contrast and less motion artifacts. It can be performed in an outpatient setting because only intravenous sedation is required. It is also less expensive than catheter angiography. Conventional catheter angiography has been replaced by 3DCTA in our institute as the standard evaluation for pre- and post-transplant cases, either living donor or recipients, for both adult and pediatric cases.

In conclusion, the clinical experience with multislice 3DCTA in our institute has been encouraging. The accuracy provided by its noninvasiveness and fast and easy interpretation with 3D images should be advocated as a superior option to other conventional examinations.

References

1. Tzakis AG, Gordon RD, Shaw BW JR, Iwatsuki S, Starzl TE. Clinical presentations of hepatic artery thrombosis after liver transplantation in the cyclosporine ERA. Transplantation 1985; 40:667–671.
2. Wozney P, Zajko AB, Bron KM, Point S, Starzl TE. Vascular complications after liver transplantation: A 5-year experience. AJR Am J Roentgenol 1983;147:657–663.
3. Flint EW, Sumkin JH, Zajko AB, Bowen A. Duplex sonography of hepatic artery thrombosis after liver transplantation. AJR Am J Roentgenol 1988;151:481–483.
4. Buell JF, Funaki B, Cronin DC, et al. Long-term venous complications after full-size and segmental pediatric liver transplantation. Ann Surg 2002;236:658–666.
5. Cheng YF, Huang TL, Chen CL, et al. Intraoperative Doppler ultrasound in liver transplantation. Clin Transplant 1998;12: 292–299.
6. Katyal S, Oliver JH III, Buck DG, Federle MP. Detection of vascular complications after liver transplantation: Early experience in multislice CT angiography with volume rendering. AJR Am J Roentgenol 2000;175:1735–1739.
7. Brancatelli G, Katyal S, Federle MP, Fontes P. Three-dimensional multislice helical computed tomography with the volume rendering technique in the detection of vascular complications after liver transplantation. Transplantation 2002;73:237–242.
8. Cheng YF, Chen CL, Jawan B, et al. Multislice CT angiography in pediatric liver transplantation. Transplantation 2003;76:353–357.
9. Dalgic A, Dalgic B, Demirogullari B, et al. Clinical approach to graft hepatic artery thrombosis following living related liver transplantation. Pediatr Transplant 2003;7:149–152.
10. Chiang YC, Chen CL, Chen YS, et al. Hepatic artery reconstruction using microsurgical technique in liver transplantation. Transplant Proc 1996;28:2417–2419.
11. Dodd GD III, Memel DS, Zajko AB, Baron RL, Santaguida LA. Hepatic artery stenosis and thrombosis in transplant recipients: Doppler diagnosis with resistive index and systolic acceleration time. Radiology 1994;192:657–661.
12. Quiroga S, Sebastia MC, Margarit C, Castells L, Boye R, Alvarez-Castells A. Complications of orthotopic liver transplantation: Spectrum of findings with helical CT. Radiographics 2001;21:1085–1102.
13. Guckelberger O, Bechstein WO, Langrehr JM, et al. Successful recanalization of late portal vein thrombosis after liver transplantation using systemic low-dose recombinant tissue plasminogen activator. Transpl Int 1999;12:273–277.
14. Lerut J, Gordon RD, Iwatsuki S, Starzl TE. Surgical complications in human orthotopic liver transplantation. Acta Chir Belg 1987;87:193–204.
15. Egawa H, Tanaka K, Uemoto S, et al. Relief of hepatic vein stenosis by balloon angioplasty after living-related donor liver transplantation. Clin Transplant 1993;7:306–311.