ULTRASOUND IMAGING OF VASCULAR COMPLICATIONS AFTER ADULT ORTHOTOPIC LIVER TRANSPLANTATION

Authors: R. Lukšaitė[1], A.Samuilis[1], V. Sokolovas[2], A.E Tamošiūnas[1], K.Strupas[2].

[1] Department of Radiology, Nuclear Medicine and Medical Physics, Institute of Biomedical Sciences, Faculty of Medicine, Vilnius University.
[2] Clinic of gastroenterology, nephro-urology and surgery, Institute of Clinical Medicine, Faculty of Medicine, Vilnius University.

ABSTRACT
Liver transplantation is important treatment option for end-stage liver disease. With the gradual improvements in surgical technique and immunosuppression therapy, liver transplantation became the first line treatment for acute or chronic end stage liver disease, and in some cases malignancies or metabolic disorders. Vascular complications are the most common and dreaded complications on the early period after liver transplantation. Arterial thrombosis is the one that has most severe or even life threatening outcome. Early diagnosis of these complications can lead to early treatment and better graft and patient survival results and imaging plays a crucial role in the diagnosis of vascular complications. Ultrasound is the first choice imaging modality in early postoperative period, because of its availability, portability and good sensitivity in detecting vascular complications. This article describes the normal and transient vascular ultrasound findings after liver transplantation, reviews vascular complications after orthotropic liver transplantation and presents several clinical cases from our transplantation center.

Keywords: orthotopic liver transplantation, vascular complications, ultrasound

INTRODUCTION

Liver transplantation is important treatment option for end-stage liver disease. The most common indications for liver transplantation are listed in Table 1 and liver cirrhosis is most frequent of all (52%). According to European Liver Transplantation registry (ELTR) there is about 6000 liver transplantations per year in Europe and similar amount is in United States (1). First successful orthotopic liver transplantation (OLT) was performed by Thom Starzl from Colorado university in 1967 (2). Unfortunately till 1988 one year survival was only up to 33%. Gradual improvements in surgical technique, better selection of patients and improved postsurgical management of complications and immunosuppression therapy led to better one year survival rates up to 81% (1). However there is still considerable amount of postoperative complications after liver transplantation. There are few different classifications of postoperative complications one of them is made according to the origin of complications is listed in Table 2. Another way to classify post-operative complications is according to timing excluding two main groups of early (up to one month after OLT) and late (more than one month after OLT) complications (4). In the early post-operative period vascular complications are one of the main causes of patient morbidity and death (1). Nowadays the incidence of vascular complications is generally about 7.2-15% (4). In cases such as split liver transplantation, live donor liver transplantation or children liver transplantation rate can be as high as 20% (5,6). Arterial complications are the most common (5-10%) vascular complications after OLT. Early hepatic artery thrombosis more often may need retransplantation while venous complications including portal and caval venous problems are less frequent and can usually be treated by surgical or endovascular intervention (5).

As there are no specific clinical or laboratory features of arising vascular complications imaging has the pivotal role in posttransplantation period

Table 1 Indications for liver transplantation (3).

Acute liver failure	• Hepatitis A/B • Intoxication (e.g., acetaminophen, death cap) • Wilson's disease • Budd–Chiari syndrome
Chronic liver failure: Non-cholestatic cirrhosis	• Hepatitis B/C • Autoimmune hepatitis • Alcohol-induced cirrhosis
Chronic liver failure: Cholestatic cirrhosis	• Primary biliary cirrhosis (PBC) • Primary sclerosing cholangitis (PSC) • Secondary biliary cirrhosis
Chronic liver failure: Metabolic	• Wilson's disease • Hemochromatosis • α-1 Antitrypsin deficiency • Amyloidosis • Cystic fibrosis
Chronic liver failure: Vascular	• Tyrosinemia • Budd–Chiari syndrome
Other indications	• Primary oxalosis • Gycogen storage diseases • Hyperlipidemia • Polycystic liver disease
Malignant disease	• Hepatocellular carcinoma (within Milan criteria) • Fibrolamellar carcinoma • Hepatoblastoma • Epitheloid hemangioendothelioma • Cholangiocellular adenocarcinoma • Neuroendocrine liver metastases
Benign liver tumors	• Adenomatosis

to monitor the transplant allograft and screen for possible complications. Early detection of complications is essential to ensure appropriate treatment and preserve graft function (7). Ultrasound (US) is the first line imaging modality, because of its availability, portability, and cost effectiveness, also it has no radiation or nephrotoxic effect of contrast media.

On the other hand, there are some shortcomings of this modality as it is very much operator dependent and the evaluation may be difficult depending on patient constitution type or lack of suitable acoustic window. The use of a contrast enhanced US (CEUS) may help improve the sensitivity of the modality for detection of slow vascular flow or small intraluminal thrombus (9). CEUS can be performed at the bedside in the intensive care unit, avoiding most of the risks associated with contrast enhanced computed tomography (CT) or angiography (10). Another alternative, that may improve US imaging in difficult to image cases are new vascular imaging techniques such as B-flow (General Electric Healthcare) (Video 1-2), eFlow (Hitachi Medical Systems) or Superb Micro-Vascular Imaging (SMI, Toshiba Medical Systems) (Video 4-5), that do not require contrast media, but allows to depict low-velocity microvascular blood flow and has a high temporal and spatial resolution

Video 1. Patient after liver transplantation. Ultrasound B-flow scale. Common hepatic artery and portal vein visualised. ***(Click to play video)***

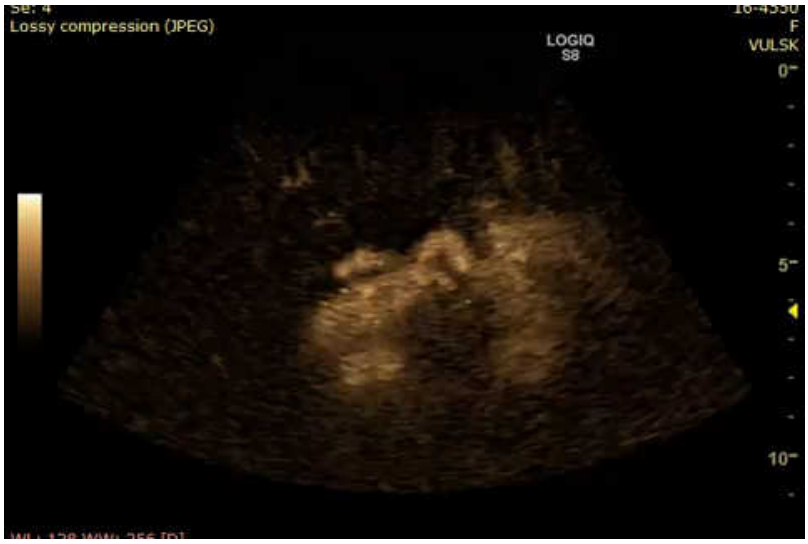


Table 2 Classification of postoperative complication after liver transplantation according origin (8).

Vascular complications	Biliary complications	Other complications
Hepatic artery:	• Obstruction	Infection, abscess
• Thrombosis	• Stones	Hematoma
• Stenosis	• Stricture	Neoplasm
• Pseudoaneurysm		Cirrhosis and its complications
Portal vein:	**Bile leak and biloma**	Rejection
• Thrombosis		Bowel perforation
• Stenosis		
• Pseudoaneurysm		
Inferior caval vein or hepatic veins:		
• Thrombosis		
• Stenosis		

(11). Multidetector contrast enhanced computer tomography or magnetic resonance imaging (MR) may be employed as second step imaging modalities in unclear situations. Digital subtraction angiography (DSA) is usually chosen when endovascular treatment is planned along with the diagnostic imaging. Diagnostic imaging algorithm is listed in Table 3.

Table 3 Imaging evaluation of vascular and biliary complications after orthotopic liver transplantation (8) .

Type of complication	Initial study	Subsequent study	Final invasive study
Vascular	Vascular ultrasound	CEUS CT angiography, MR angiography	Digital subtraction angiography
Biliary	Greyscale ultrasound	MR cholangiopancreatography, CT, Hepatobiliary scintigraphy	ERCP, percutaneous transhepatic cholangiography

CEUS – contrast enhanced ultrasound; CT – computed tomography; MR – magnetic resonance; ERCP – endoscopic retrograde cholangioprancreatography.

SURGICAL TECHNIQUE

Orthotopic liver transplantation requires total hepatectomy and substitution of the native liver by donor liver in the right hypochondrium. Usually it includes three vascular anastomoses: hepatic artery (HA), portal vein (PV) and inferior vena cava (IVC). HA anastomosis is usually "fish-mouth" type end-to-end anastomosis and its location depends on the length and calibre of the vessel but is typically performed near the branch point of gastroduodenal and proper hepatic arteries of the recipient (12,13). In case of atypical arterial anatomy additional and more complicated arterial reconstructions may be necessary. In the event of recipient hepatic artery or celiac axis high-grade stenosis an aortohepatic interposition jump graft using donor iliac artery may be used (14). The donor and recipient portal veins are usually anastomosed end-to-end. Although tapered anastomosis may be required when a significant size mismatch exists between the recipient and the donor veins (15). PV thrombosis used to be an absolute contraindication to liver transplantation but is no longer a contraindication, because a segment of donor-derived iliac vein may be used as an interposition jump graft anastomosed to the recipient superior mesenteric vein (7).

There are several surgical techniques for IVC anastomosis. The main difference between them is that recipient hepatectomy may or may not include the retrohepatic IVC segment. In the older standard approach, the recipient's retrohepatic IVC is removed with the diseased liver, and end-to-end anastomosis of the recipient and donor IVCs is performed twice (12). The other technique that is presently used in most institutions is IVC preserving or "piggyback" technique. Several methods of graft-to-inferior vena cava implantation during orthotopic liver transplantation with preservation of the caval flow have been described (16). In our center we use the "piggy-back" modified by Belghiti technique, when a side-to-side anastomosis is created between two newly made openings: one on the anterior wall of the recipient IVC and other on the posterior wall of donor IVC. Both sides of donor IVC are closed. The main advantage of the caval preservation achieved with the "piggyback" technique is hemodynamic stability, a result of continued blood flow from the lower extremities and renal veins throughout the surgery (17). The main disadvantage is that there is still a risk of complications and most often of them are Budd-Chiari syndrome and liver parenchyma bleeding caused by parenchyma injury while creating anastomosis.

POSTOPERATIVE ULTRASOUND

US is the first line imaging modality in evaluation, detection, and follow-up of vascular complications after OLT. Doppler US screening protocols for vascular complications are highly variable among different transplantation centers with respect to frequency and interval of screening, and the time period after operation during which screening was performed (18). Usually first US examination is performed in first 24h after OLT and further follow-up may be done every day for the first week or may be repeated only 5-7 days after OLT, or even it may be chosen to repeat the examination only when it is clinically indicated (19–21).

Some transplantation centers also use intraoperative Doppler US, just after vascular anastomoses are created. Main advantage of intraoperative Doppler US is that we can evaluate vascular anastomoses and make an early diagnosis of possible complications, when appropriate action can be done on the same time, avoiding additional laparotomies and also possible consequences to the graft function and bile ducts ischemia (22, 23).

Nevertheless, which protocol is chosen, standard US evaluation of the postoperative liver transplant should consist of grayscale examination of the liver parenchyma, bile ducts and surrounding structures and grayscale, colour and pulsed Doppler evaluation of HA, PV, hepatic veins and IVC at the site of anastomosis and intrahepatic branches (14). Awareness of the normal US appearance of the transplanted liver and possible transient findings permits detection of complications and prevents misdiagnoses.

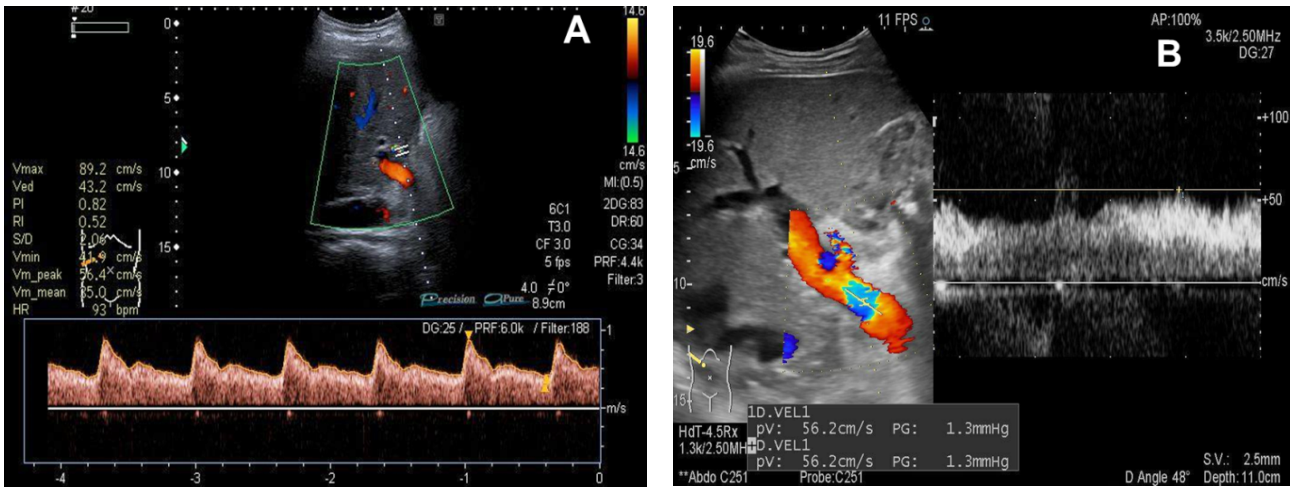
The normal HA should show a pulsatile antegrade, low resistance waveform with continuous diastolic blood flow (Figure 1 A) (24). The

acceleration time (AT), which represents the time from end diastole to the first systolic peak, should be less than 0.08 s, and the resistive index (RI), which represents the ratio of (peak systolic velocity- end diastolic velocity)/peak systolic velocity, should be between 0.5 and 0.8 (24,25). It is important to evaluate the right and left HA branches, because a normal hepatic artery waveform obtained at the porta hepatis does not exclude a hepatic artery obstruction. Whenever possible, the anastomosis also should be examined (9). The most common transient hepatic arterial waveform abnormality seen in the immediate postoperative period is increased hepatic arterial RI, due to decreased diastolic flow (19). This transient elevation of RI is likely secondary to allograft oedema, increased cold ischemia time, increased portal flow or vessel spasm (26). The other causes of abnormal RI are listed in Table 4. Although the mean normal hepatic arterial peak systolic velocity (PSV/Vs) is 103 cm/s, in the early period even in healthy liver it may vary from 13.2 up to 367 cm/s (12,21). Elevated hepatic arterial velocity in the immediate postoperative period may be caused by transient persistence of the preoperative high-arterial-inflow state, which is caused by portal hypertension (21). Also higher velocity at the anastomosis site

Table 4. Causes of elevated and decreased hepatic artery resistance (12,24,27).

Causes of elevated hepatic artery resistance	Causes of decreased hepatic artery resistance
Pathologic (microvascular or disease) • Chronic hepatocellular disease (including cirrhosis) • Hepatic venous congestion • Transplant rejection • Any other disease that causes diffuse compression or narrowing of peripheral arterioles	**Proximal arterial narrowing** • Transplant stenosis • Atherosclerotic disease (celiac, hepatic) • Arcuate ligament syndrome
Physiologic • Postprandial state • Advanced patient age	**Distal (peripheral) vascular shunts (arteriovenous, arterioportal fistula)** • Cirrhosis with portal hypertension • Posttraumatic or iatrogenic causes • Hereditary haemorrhagic telangiectasia (Osler-Weber-Rendau syndrome)
Transient (early postoperative period) • Oedema • Increased cold ischemia time • Increased portal flow • Vessel spasm • Older age of liver donor	**Transient (early postoperative period)** • Liver oedema • Oedema at the anastomosis site • Systemic hypotension

Figure 1. Normal hepatic artery and portal vein flow on Doppler ultrasound after orthotopic liver transplantation A. US triplex scan image. Normal arterial blood flow in hepatic artery: pulsatile antegrade low resistance waveform Vs. 89 cm/s, RI 0,52. B. US triplex scan image. Normal blood flow in portal vein: hepatopetal spectral waveform Vmax. 56,2 cm/s.



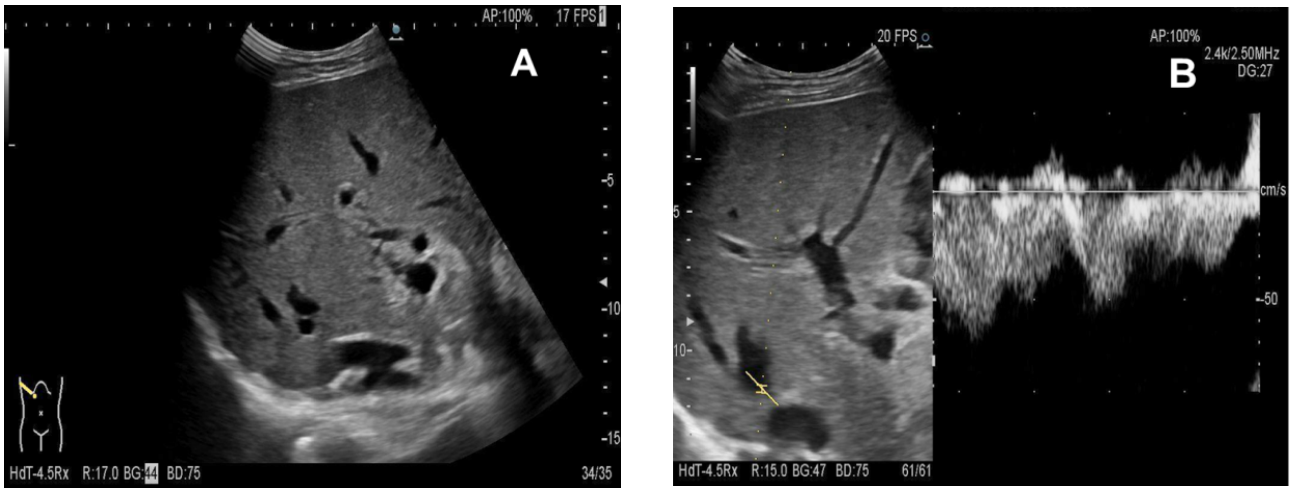
might be caused by surrounding tissue oedema. Also in case of arterial kinking the angle of insonation should be set correctly (up to 60 degrees) to make and appropriate differentiation from true arterial stenosis. Doppler US arterial waveform abnormalities on the immediate postoperative scans should be followed and correlated with the patient's clinical findings including liver function laboratory tests. Transient HA waveform changes usually resolve in 7-15 days (19).

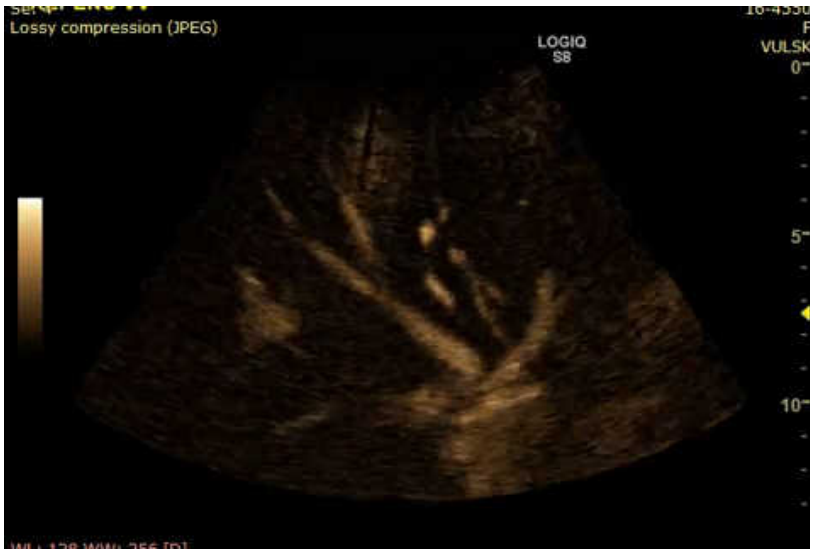
The normal PV Doppler waveform is a continuous flow pattern toward the liver with mild velocity variations induced by respiration (Figure 1 B) (27). The blood flow mean velocity at the anastomosis site is normally about 58 cm/s (12). However increases in PV velocities can be seen in immediate postoperative period likely because of compressibility caused by postoperative inflammation or fluid collections (20). The velocity should decrease gradually on a first week after transplantation, but M. Bolognesi et al in his study declares that portal blood flow may decline gradually for up to 2 years after liver transplantation (21,28).

Normal Doppler wave appearance of the hepatic veins and IVC shows a phasic flow pattern (conventionally triphasic), reflecting the physiologic changes in the blood flow during the cardiac cycle (Figure 2) (27).

But on early postoperative period monophasic or biphasic waveforms are commonly seen secondary to graft oedema or compression by the adjacent fluid collection. This usually normalises on follow-up studies in a few days (19).

Figure 2. A. Ultrasound greyscale image. Vena cava inferior „pigg-back" modyfied by Belghiti anastomosis axial view. B. Ultrasound duplex scan image. Right hepatic vein triphasic spectral vaweform.





Video 2. Patient after liver transplantation. Ultrasound B-flow scale. Active flow in hepatic veins and vena cava inferior anastomosis.

ARTERIAL COMPLICATIONS

THROMBOSIS

HA thrombosis is the most frequent of all arterial complications following OLT and is found in 2-12 % of cases (29) . J. Bekker et al. in his systematic review reported the median time to detection of HA thrombosis was 6.9 days (range 1–17.5 days postoperative) (18). Although the real causes of HA thrombosis are is still a source of debate usually early HA thrombosis is mainly associated with technical (surgical) problems such as difficult anastomosis, kinking, stenotic anastomosis, small vessel size, reduction in a disparate diameters of the arteries, the presence of multiple arteries, aberrant or complex donor/recipient arterial anatomy or arterial abnormalities requiring complex arterial reconstructions, use of aortic conduit and etc. (18,30,31). Those problems are more common among centers performing fewer than 30 OLT a year; the incidence of HA thrombosis diminishes with the surgical team's experience. Therefore, surgical causes probably do not represent the main risk factor for HA thrombosis (4). Regarding nonsurgical risk factors involved in the appearance of HA thrombosis, we can identify donor age >60 years, extended cold ischemia time, lack of ABO compatibility, cigarette smoking, hypercoagulability, preservation damage to the endothelium, a donor positive for cytomegalovirus (CMV) and CMV-negative in a recipient (31).

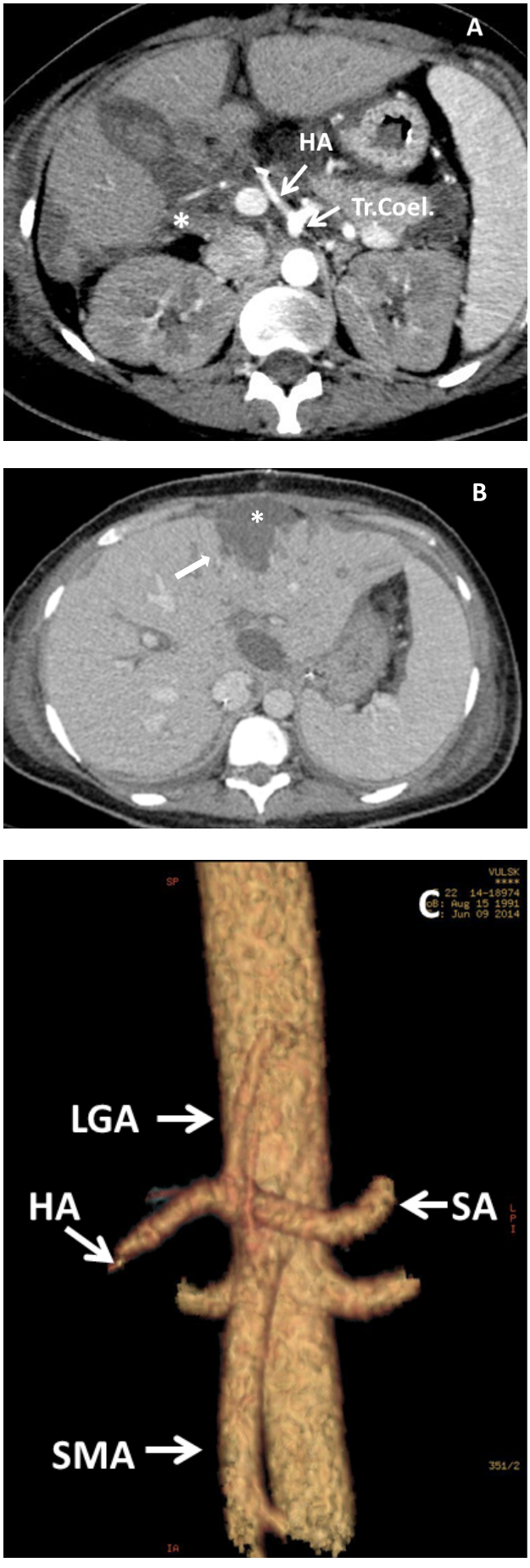


Figure 3. Female patient E.P., 22 years old, days 11 days afer orthotopic liver transplantation. A-C. CTA arterial phase images, axial plane (A) and 3D (C) reconstructions, no contrast media in donor hepatic artery or intrahepatic arterial branches - hepatic artery thrombosis. B. CTA portovenous phase images, ischemic zone (arrow) in 4A liver segment and perihepatic fluid colection (asterisk). CTA- computed tomography angiography. HA – hepatic artery, Tr. Coel. – truncus coeliacus, LGA – left gastric artery, SA – splenic artery, SMA – superior mesenteric artery.

Without prompt treatment HA thrombosis carries an incidence of graft failure and mortality of more than 50% (4). The bile ducts in a liver transplant are supplied exclusively by small branches of the hepatic arteries, so hepatic artery thrombosis can lead to biliary ischemia, strictures and necrosis (Video 3, Figure 6) (13). Up to 50% of patients with late HA thrombosis can be asymptomatic with only elevated liver transaminases (9). Symptomatic patients often present with biliary complications with recurrent cholangitis, abscess and biliary leakage or stricture, and the presentation may be insidious (Figure 3-6) (5). Indeed, clinical expression depends on the existence of collaterals, which can develop as early as within two weeks. Prompt diagnosis of hepatic artery thrombosis is extremely important because early intervention (with thrombectomy, hepatic artery reconstruction, or both) may allow graft salvage (25). The rate of retransplantation in untreated HA thrombosis is 25-83% while it is 28-35% in patients who underwent revascularization (5).

A US-based diagnosis of hepatic artery thrombosis is established in the absence of flow in the hepatic and intrahepatic arteries at colour and pulsed Doppler imaging. The Doppler US imaging findings allow correct diagnosis in an estimated 92% of cases (25). The sensitivities of duplex Doppler imaging compared with angiography are 100% for the detection of early hepatic artery thrombosis and 72.7% for late hepatic artery thrombosis (32). Nevertheless, CTA and DSA should be considered as second step imaging choice (Figure 3-4).

Temporal progression of Doppler sonography findings from initially normal diastolic flow to absent diastolic flow, dampening of the systolic peak, and finally complete loss of hepatic arterial flow has been described as the "syndrome of impending thrombosis" and is a strong predictor of hepatic artery thrombosis (33).

Figure 4. Female patient, 22 years old, 11 days after orthotopic liver transplantation hepatic artery thrombosis occurred, percutaneous angioplasty treatment (thrombectomy, balloon dilatation and stent placement in hepatic artery) was done. A. DSA image after hepatic artery recanalization and angioplasty, recipient and donor hepatic artery segments and its branches are filled with contrast media. B. CTA arterial phase 3D reconstruction image. Hepatic artery patency is restored, anastomotic site stent (asterisk). CTA - computed tomography angiography; DSA – digital subtraction angiography; HA – hepatic artery; SMA – superior mesenteric artery; SA – splenic artery.

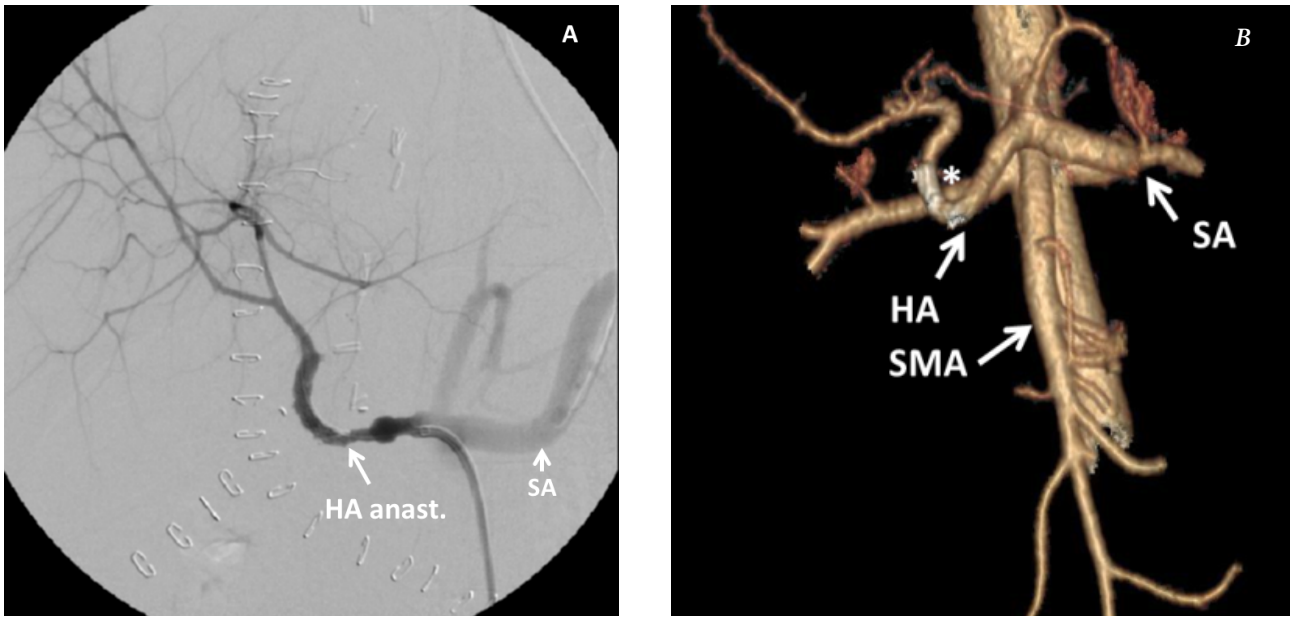
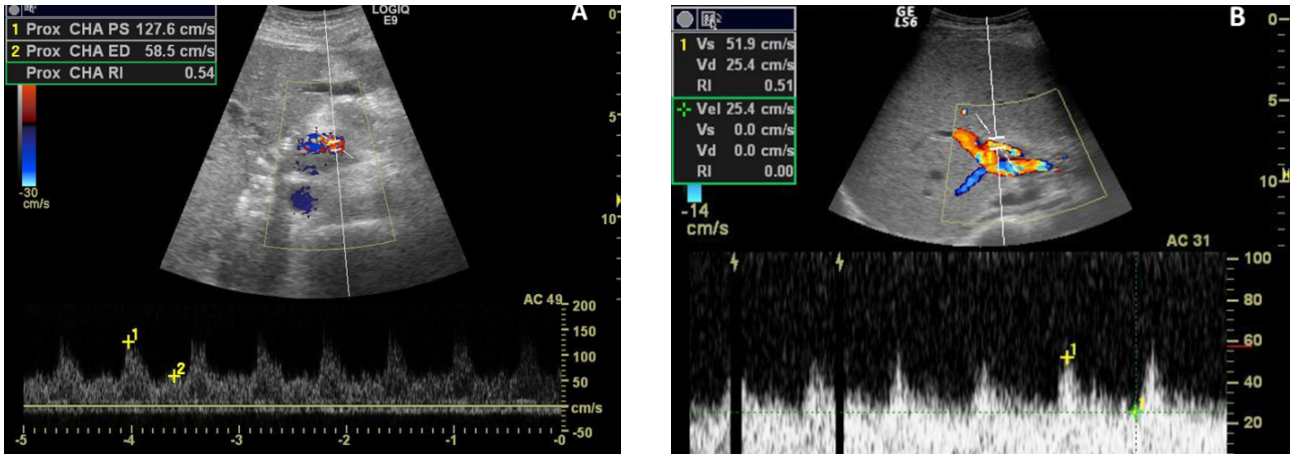


Figure 5. Female patient, 22 years old, on 11th day after orthotopic liver transplantation hepatic artery thrombosis occurred, percutaneous angioplasty and stenting was done, control Doppler ultrasound exam on the next day. A. Normal arterial flow waveform at the anastomosis Vs 127 cm/s, RI 0.54. B. Normal arterial flow in the right intrahepatic branch, Vs 52 cm/s, RI 0.51.



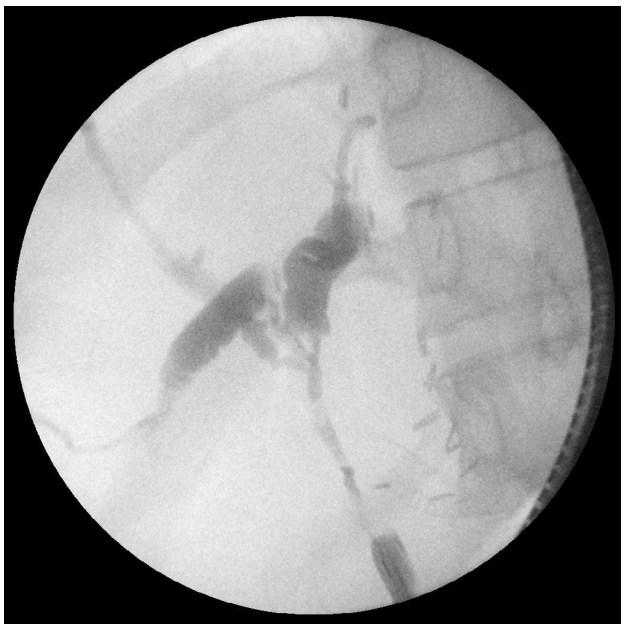
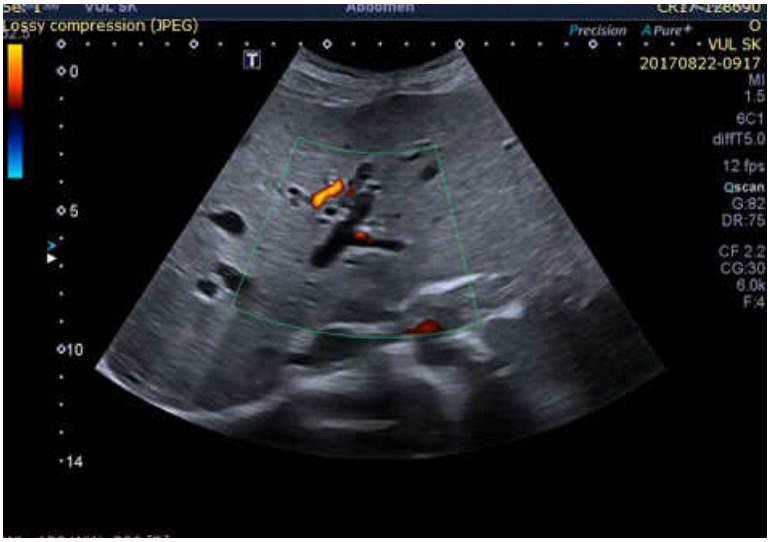


Figure 6. Female patient, 22 years old, on 11th day after orthotopic liver transplantation hepatic artery thrombosis occurred, percutaneous angioplasty and stenting was done. One and a half month after treatment intrahepatic cholestasis and extrahepatic bile duct stricture occurred. Endoscopic retrograde cholangiopancreatograpgy image.



Video 3. Ultrasound color Doppler scale. Female patient, 22 years old, on 11th day after orthotopic liver transplantation hepatic artery thrombosis occurred, percutaneous angioplasty and stenting was done. One and a half month after treatment intrahepatic cholestasis occurred.

Reduced flow, whether secondary to spasm or to low cardiac output, can also cause non-visualization of flow at Doppler US and be a cause of false positive diagnosis (8). In such cases microvascular ultrasound imaging techniques or even CEUS might be useful to clarify the diagnosis.
Also hepatic arterial collaterals may develop in chronic thrombosis and demonstrate low intrahepatic arterial RI, mimicking stenosis and giving a false-negative diagnosis. Therefore, the sensitivity of ultrasound for the detection of hepatic artery thrombosis decreases as the interval following transplant increases (25).
Currently, the literature on the curative management of early HAT suggests the following procedures: first endovascular radiological intervention (intra-arterial thrombolysis, percutaneous transluminal angioplasty and stent placement) (Figure 4-5), secondly open surgical revascularization, and finally liver retransplantation, which is associated with the best survival rate compared with revision or thrombolysis, but is a limited therapeutic option due to organ shortage (4).

STENOSIS

HA stenosis has been reported to occur in 5%–11% of liver transplant recipients (25). Many patients with HA stenosis are asymptomatic and most commonly present only with abnormal liver function tests. This complication usually occurs at the site of anastomosis within 3 months after transplantation. If left untreated, it may lead to hepatic artery thrombosis, hepatic ischemia, biliary stricture, sepsis, and graft loss. Early detection of hepatic artery stenosis is crucial to allow treatment either with surgical reconstruction or with balloon angioplasty, or stent placement and avoid the necessity of retransplantation (7).
Doppler US is reported to have a sensitivity of 100%, a specificity of 99.5% a PPV of 95% and NPV of 100%, and overall accuracy of 99.5% in early diagnosis of HAS (34).
Doppler US findings include increased peak systolic velocity (>200 cm/s) at the stenosis site, and a low RI (< 0.5), a long AT (> 0.08 seconds), and a "tardus-parvus" waveform distal to the stenosis (Figure 7) (8).
Severe aortoiliac atherosclerosis and hepatic artery thrombosis with the formation of intrahepatic collateral vessels are two important pitfalls giving false-positive results, because flow through collateral vessels also may demonstrate a dampened arterial waveform (9).
In cases of false-negative results with Doppler US, the CEUS examination may be helpful. The microbubbles may boost the amplitude of the Doppler signals from the blood and improve the signal-to-noise ratio when the Doppler signals from the hepatic vasculature are severely attenuated (e.g. in severe HA stenosis), the so-

Figure 7. Female patient, 22 years old, 2 years after othotopic liver transplantation, and hepatic artery stenting, stenosis occured at arterial anastomosis. A. Ultrasound triplex image at hepatic artery stent site, low resistance pulsatile arterial vaweform is seen with a very high systolic velocity up to 392 cm/s. B. Ultrasound triplex image of right liver arterial branch, „tardus-parvus" type vaweform" is registered with a low resististance index (RI 0,36), and prolonged acceleration time.

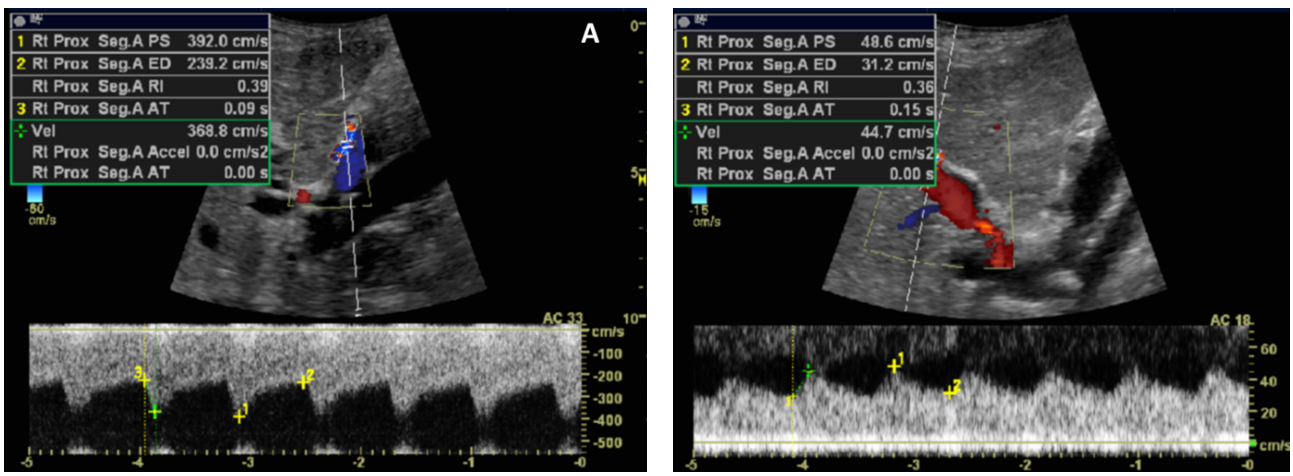
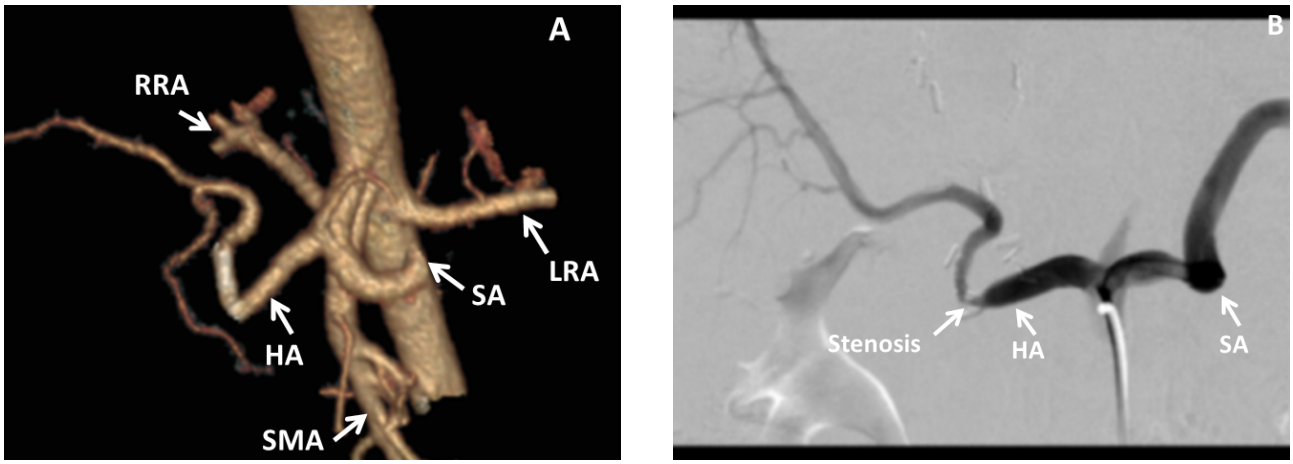


Figure 8. Female patient, 22 years old, 2 years after othotopic liver transplantation, and hepatic artery stenting. On control Doppler ultrasound exam suspicion of arterial stenosis, so CTA and DSA was done. A. CTA arterial phase 3D reconstruction, hepatic artery stenosis (75 %) at the proximal part of endoluminal stent, baucause of stent angulation. B. Digital subtraction angiography shows hepatic artery stenosis baloon dilatation was successfully performed. CTA – computed tomography angiography; DSA – digital subtraction angiography; RRA – right renal artery; LRA – left renal artery. HA – hepatic artery; SMA – superior mesenteric artery; SA – splenic artery;



called Doppler rescue (35). When CEUS is not available new non-contrast microvascular ultrasound imaging techniques such as SMI, B-Flow or e-Flow can be useful.

Radiological endovascular intervention by percutaneous transluminal angioplasty with or without stent placement is often used to treat posttransplant HAS (Figure 8) and are both efficacious, with 7% to 12% of complications including dissection and arterial rupture, restenosis or thrombosis (25%) and failed attempts (12%). Surgical revision and retransplantion showed a high rate of success, but the overall mortality rate was as high as 20% (4).

PSEUDOANEURYSM

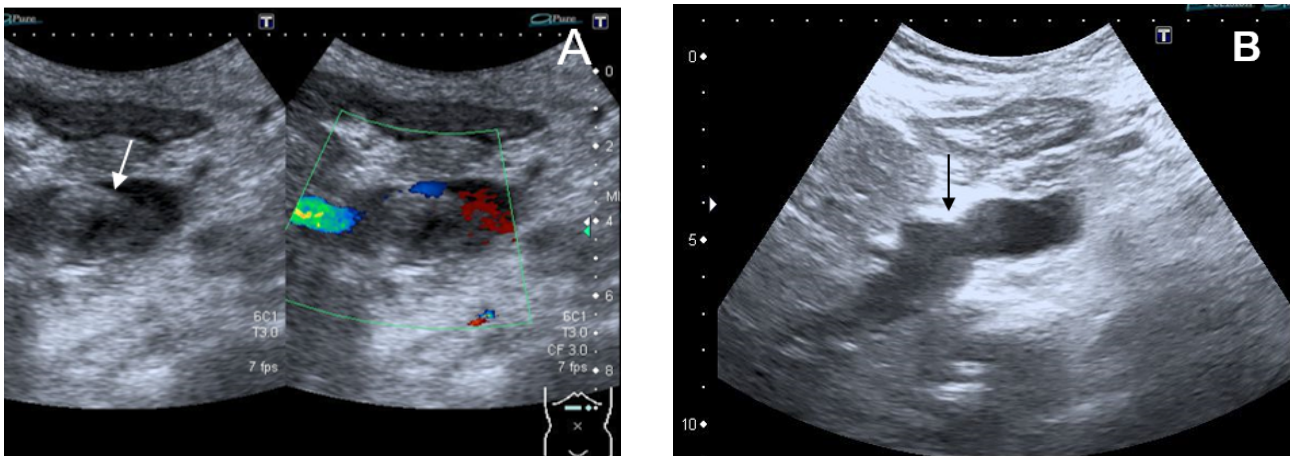
Arterial pseudoaneurysms are rather rare complications after OLT and occur only in up to 3% of cases(4). Nevertheless this condition may be life threatening and is associated with more than 50% mortality (5). Pseudoaneurysms may be intrahepatic and extrahepatic, the latter are more frequent and usually form at the location of arterial anastomosis or at the site of ligation of donor gastroduodenal artery (36). An intrahepatic pseudoaneurysm occurs as a consequence of a liver biopsy or after a focal parenchymal infection (27). Timely diagnosis is important because of impending rupture and life-threatening haemorrhage. On Doppler US images, a hepatic artery pseudoaneurysm appears as a cystic structure, usually near the course of the hepatic artery; its lumen is colour-filled, demonstrating a turbulent arterial flow, or "yin and yang" sign (9). It is important to note that US depiction of a fluid collection near the arterial anastomosis on the greyscale requires further evaluation with Doppler US to rule out pseudoaneurysm (8). Usually pseudoaneurysms may be treated by either endovascular or surgical procedures and both may be equally effective. However patients who undergo angioembolisation have more rapid bleeding control and shorter hospital stay after the treatment (37).

PORTAL VEIN COMPLICATIONS

THROMBOSIS

Acute PV thrombosis is rare after liver transplantation, with a reported incidence between 1 % and 2 % (35). Early PV thrombosis is more frequent than the late PV thrombosis with a median time to diagnosis of 5 days following OLT (range: 1 to 15 days) (4).

Figure 9. Male patient, 31 years old, 4.5 years after liver transplantation. Acute thrombosis in portal vein occurred at the site of anastomosis. A. Doppler ultrasound image heterogeneous mass is filling the lumen of the portal vein at the pre-anastomotic site – subacute portal vein thrombosis. B. The same patient ultrasound greyscale image after 6 months there is no thrombus seen in the lumen of portal vein – recanalization.



Factors associated with PV thrombosis include technical problems, small diameter of the portal vein (< 5 mm), donor-recipient PV diameter mismatch, previous splenectomy, simultaneous thrombectomy for pre-existing PV thrombosis and use of venous conduits for portal vein reconstruction. Additionally, longer cold ischemia time (> 12 h) can be a risk factor for developing venous complications. This can be due to difficulties in venoplasty (and more manipulation) before anastomosis (5).

The clinical presentation depends on the time the thrombosis occurs (4). Acute PV thrombosis during the early course after liver transplantation may result in graft failure requiring retransplantation. Portal hypertension with accompanying ascites and oesophageal varices may develop as a consequence of late portal vein stenosis or occlusion. (38).

Doppler US should be the first imaging tool used and is easily employed to evaluate vascular patency. It allows, in most cases, for an immediate non-invasive diagnosis and provides a rapid evaluation of vascular flow patency (4). US greyscale imaging of occlusive portal vein thrombosis shows an echogenic luminal thrombus with no Doppler flow, in case of partial non-occlusive thrombosis fluttering thrombus may be seen (Figure 9) (27). Thrombus appearance on ultrasound depends on its age. Usually an acute thrombus is anechoic on greyscale imaging, and only colour Doppler imaging may reveal the filling defect. This emphasizes the necessity for careful assessment of the portal vein throughout its entire length with both greyscale and colour Doppler. CEUS may aid in assessment of the severity of portal insufficiency, by demonstrating parenchymal perfusion status. It also facilitates the demonstration of a small thrombus in a peripheral portal branch (35). In unclear cases CT should be the second step choice (Figure 10-11). PV thrombosis treatment includes systemic anticoagulation therapy, catheter-based thrombolytic therapy by percutaneous radiological intervention (transhepatic or transjugular access depending of the coagulation state) with or without stent placement to portosystemic shunting (TIPS) to retransplantation in highly unresolvable cases (4).

STENOSIS

The true incidence of PV stenosis after OLT is not really known, and the only data reported in the literature concerning the incidence of venous complications is < 3% (4).

In practice, the majority of patients with PV stenosis are asymptomatic and the diagnosis of stenosis is an incidental finding detected on rou-

Figure 10. Female patient, 40 years old, first day after orthotopic liver transplantation. Computed tomography image portovenous phase multiplanar reconstruction, acute occlusive portal vein thrombosis occurred. PV – portal vein; SMV – superior mesenteric vein; SV – splenic vein; PSS – portosystemic shunts.

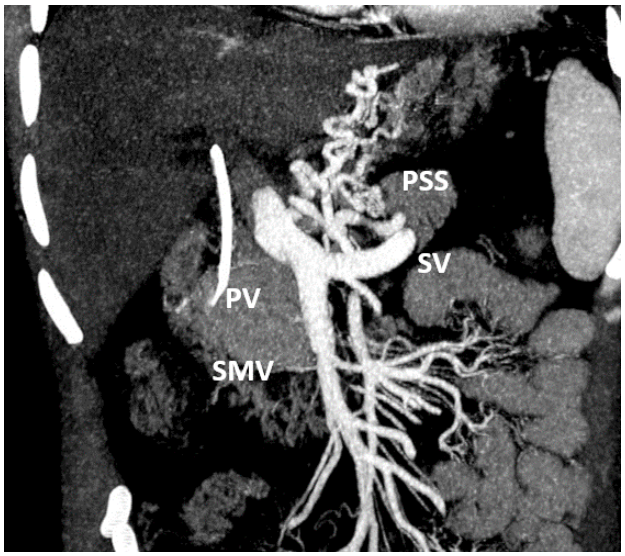
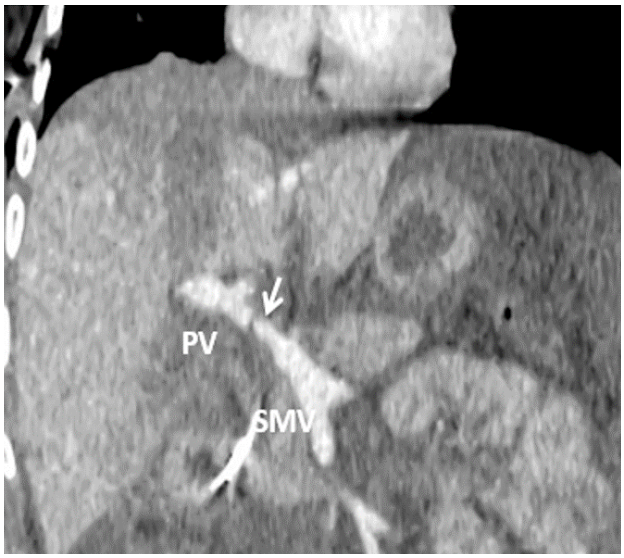


Figure 11. Male patient, 18 years old, 5th day after liver transplantation, computed tomography portovenous phase multiplanar reconstruction, non-occlusive intraluminal filling defect (arrow) in portal vein – non-occlusive portal vein thrombosis. PV - portal vein.



tine screening ultrasound (4). Only patients with high-degree stenosis (> 80%) develop symptoms. Therefore, even those patients with stenosis of the portal vein who developed symptoms such as portal hypertension with ascites and oesophageal varices could be treated conservatively (38). Nevertheless treatment is necessary as condition can evolve to thrombosis if not treated promptly. US findings of PV stenosis include narrowing of the main portal vein diameter of greater than 50% in adults or to less than a diameter of 2.5 lummen in children at the greyscale imaging, usually at the of the anastomosis (15).

Huang et al. described two Doppler US parameters for assessing PV stenosis after liver transplantation: a PV stenotic ratio greater than 50 % (pre-stenotic calibre – anastomotic site calibre/ pre-stenotic calibre) and a velocity ratio greater than 3:1 between the anastomotic and pre-anastomotic sites. Authors also found that cases of anastomotic site < 5 mm require interventional management for good long-term graft survival (39).

Chong et al. in his study reported that peak anastomotic velocity threshold of > 125 cm/s was 73% sensitive and 95% specific for stenosis (Figure 12-13). Also that a previously mentioned 3:1 velocity ratio was 73% sensitive and 100% specific for stenosis (32).

PORTAL VEIN ANEURYSMS

PV aneurysms are classified as intrahepatic and extrahepatic. Extrahepatic PV aneurysms have been defined as fusiform or saccular dilatation of main PV with luminal diameter greater than 20 mm. Intrahepatic aneurysms have been defined as lumen diameter greater than 9 mm and significantly larger than adjacent PV segments (40). Saccular structure is seen on the on the greyscale US imaging, and on Doppler US exam turbulent flow within aneurysm should be found (Figure 14).

Clinically smaller aneurysms are usually asymptomatic, whereas larger aneurysms are more often symptomatic and associated with

Figure 12. Female patient, 45 years old, one week after liver transplantation. Portal vein stenosis occurred. A. Ultrasound greyscale image, portal anastomosis site, significant narrowing of the lumen. B. Ultrasound triplex scan, high velocity blood flow at the site of portal vein anastomosis (237 cm/s).

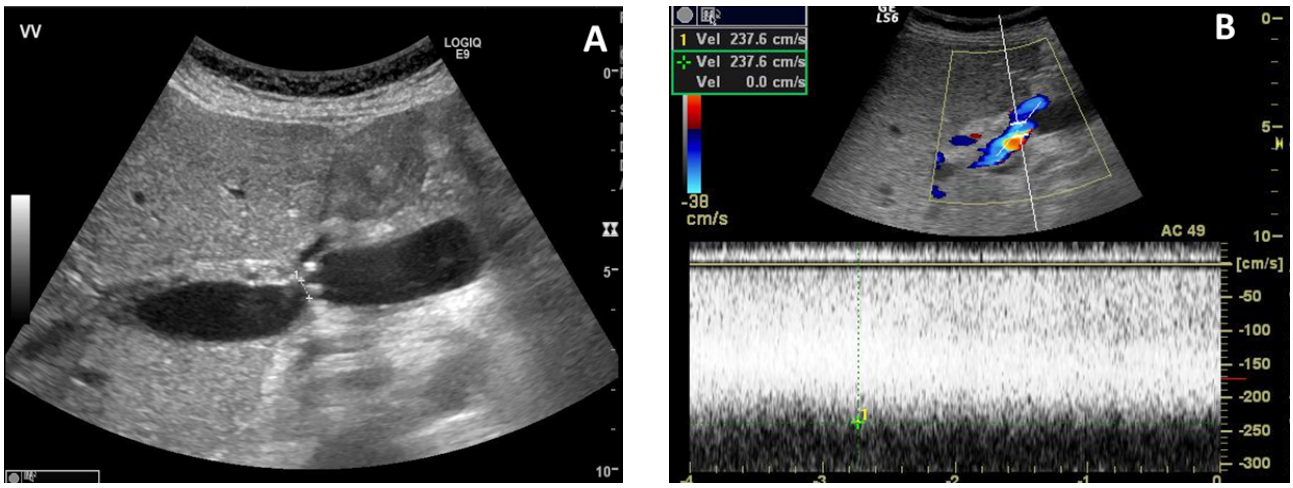
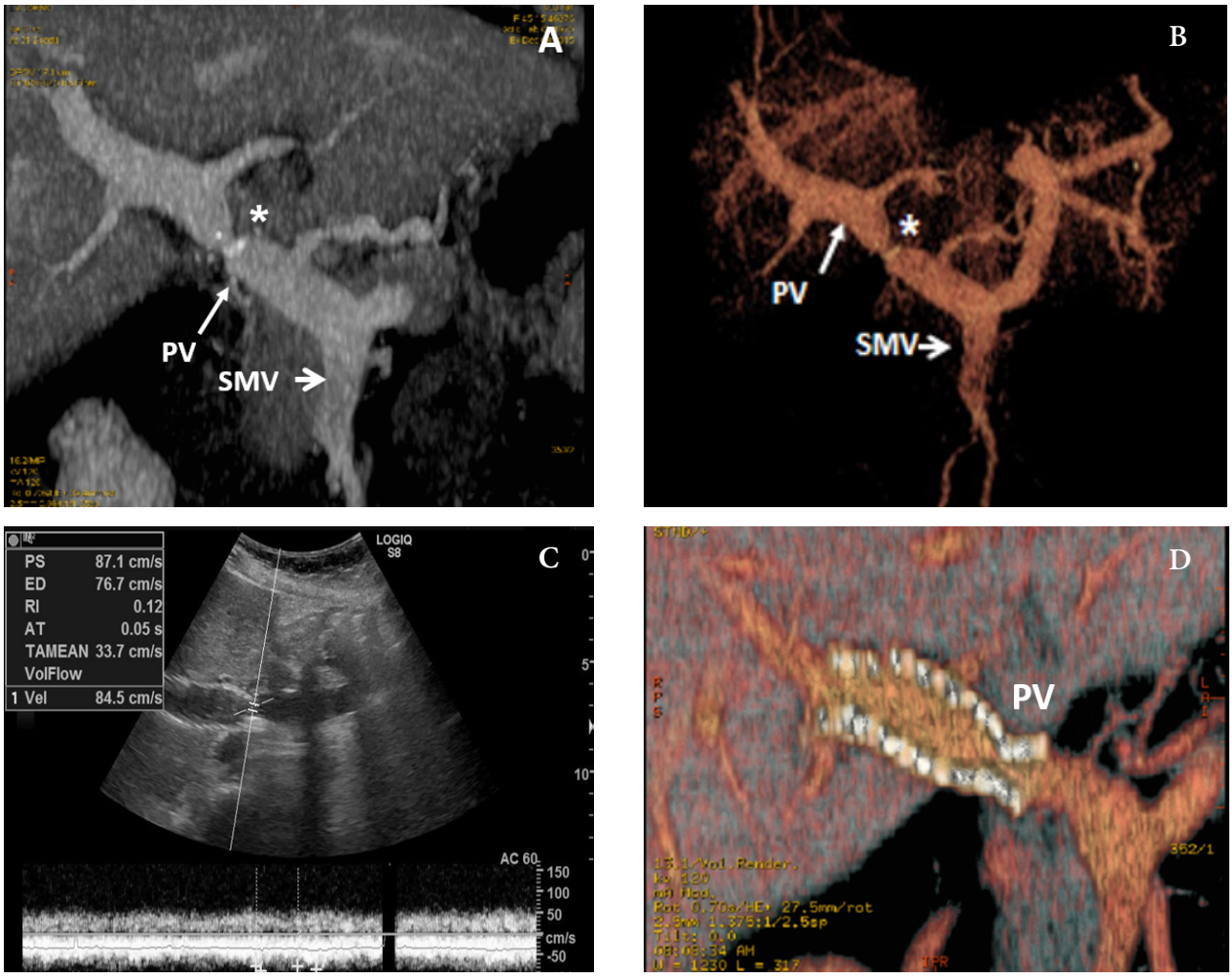


Figure 13. Female patient, 45 years old, one week after liver transplantation. Portal vein stenosis occurred (asterisk) diagnosed. A. CT portovenous phase, maximum intensity projection (MIP), portal vein stenosis up to 70 %. B. CT portovenous phase 3D rekonstruction. PV –portal vein, SMV – superior mesenteric vein. C. Ultrasound duplex scan image. The same patient after stenting procedure, normal blood flow velocity at the anastomosis site. D. CTA portovenous phase, 3D reconstruction, stent in portal vein. CT – computed tomography; PV – portal vein; SMV – superior mesenteric vein.



complications including thrombosis, portal hypertension, biliary tract obstruction caused by mass effect or rupture (14).

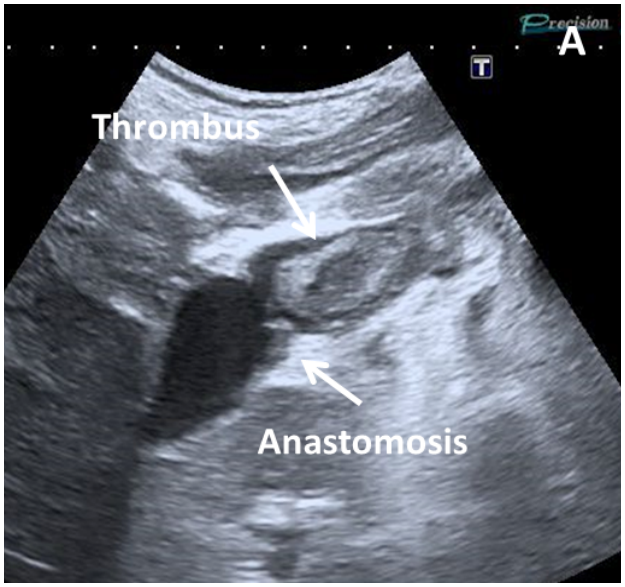
HEPATIC VEINS AND VCI COMPLICATIONS

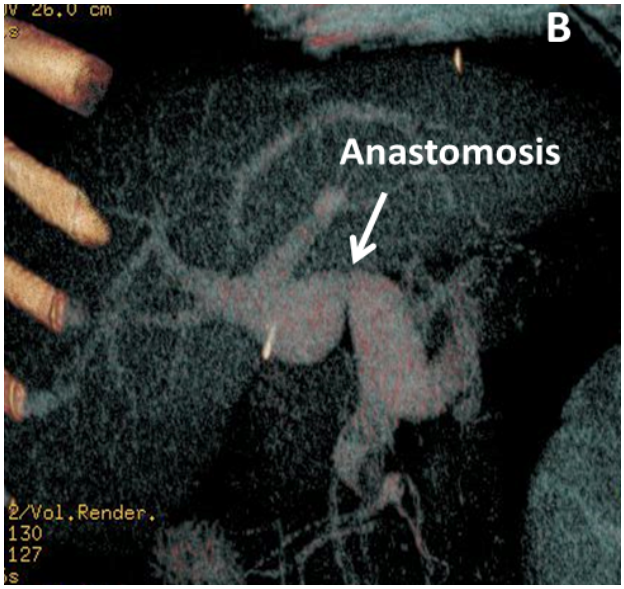
IVC complications occur in less 1% of liver transplant recipients (41). IVC stenosis and thrombosis are generally early complications occurring at the surgical anastomoses because of technical issues with the surgery (e.g. IVC kinking) and extrinsic compression from graft oedema, hematoma. Late IVC stenosis may be secondary to fibrosis and intimal hyperplasia (7).

The "piggyback" anastomosis has gained wide acceptance internationally and is the preferred technique for orthotopic liver transplantation at many institutions. However, it is especially vulnerable to two types of complications: (a) haemorrhage due to hepatic injury during surgery or due to cava-caval dehiscence (3% of cases) and (b) Budd-Chiari syndrome (0.3%–1.5% of cases) due to inadequate venous drainage (9).

Main risk factors related to IVC complications

Figure 14. Male patient, 31 years old, 4.5 years after liver transplantation. Aneurysmatic pre- and postanastomotic portal vein dilatation. A. Ultrasound greyscale image, portal vein lumen narrowing at the site of anastomosis, and aneurysmatic portal vein diltation in the preanastomotic and postanastomotic parts, chronic portal vein trombosis. B. Computed tomography portovenous phase, 3D rekonstruction. Portal vein anastomosis stenosis and aneurysmatic dilatation in preanastomotic and post-anastomotic sites.

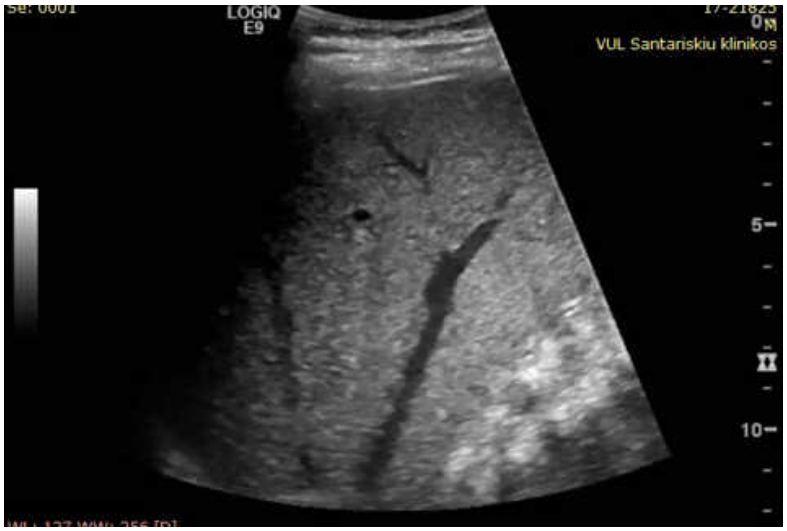




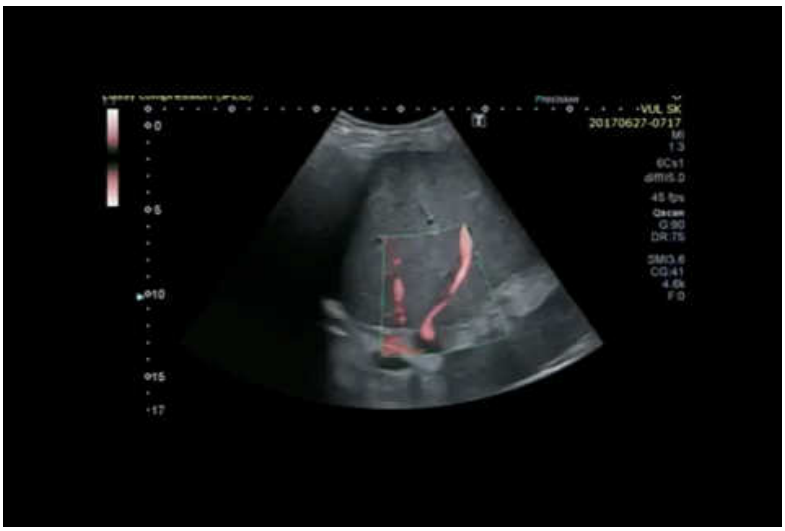
are size discrepancy between the donor and recipient vessels, suprahepatic IVC kinking from organ rotation, fibrosis, chronic thrombus, neointimal hyperplasia, hypercoagulability, compression from graft oedema and adjacent fluid collections as well as transplants in paediatric patients(6).

Patients with hepatic venous outflow obstruction usually present with massive ascites and bilateral lower limb oedema between 2 and 16 months posttransplantation, which is refractory to oral protein supplements and maximal diuretic therapy. Some of the patients can develop acute Budd-Chiari syndrome early within the first week of posttransplantation (42).

In cases of IVC stenosis Doppler US demonstrates a three- to fourfold increase in velocity compared with the unaffected IVC, and associated colour Doppler aliasing. Indirect findings include distention of the hepatic veins with dampening and loss of phasicity of the hepatic venous Doppler waveform (8). IVC thrombosis is caused by surgical factors and a hypercoagulable state (22). In venous thrombosis, the vein may appear to be expanded, with a new thrombus appearing anechoic and an old thrombus



Video 4. Male patient, 49 years old, first week after liver transplantation. Middle hepatic vein thrombosis Ultrasound grey scale video.



Video 5. Male patient, 49 years old, first week after liver transplantation. Middle hepatic vein thrombosis is seen on Ultrasound SMI scan.

appearing echogenic at US. Duplex US shows an absence of signal in the presence of complete thrombosis. Partial venous thrombosis may appear as a nonocclusive filling defect (Video 4-5) (7). Also the hepatofugal blood flow in portal vein branches may be seen.

Therapeutic management of caval and hepatic veins complications depends on the time of the presentation and the delay following OLT. In the case of severe allograft dysfunction or multi-organ failure, retransplantation is always indicated. Beyond this particular situation, percutaneous radiological intervention is the method of choice, where mortality after interventional transplant salvage procedure is 11.1% as compared with 41.6% mortality for those patients managed by retransplantation (4).

CONCLUSIONS

Although there is increasing survival of patients after OLT, the risk of complications after surgery persists. Vascular complications are ones of the most common and life threatening complications after OLT. As there are no specific clinical features or laboratory markers imaging plays the main role in making correct diagnosis. Ultrasound is the first line imaging modality for evaluating transplanted liver vasculature as it has good availability and in experienced hands may provide precise diagnosis. Nevertheless in difficult or unclear cases other imaging modalities as CT, MR or DSA should be considered.

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