SONOGRAPHIC EVALUATION OF THE TRASPLANTED LIVER: VASCULAR COMPLICATIONS

EVALUACIÓN ECOGRAFICA DEL HÍGADO TRANSPLANTADO: COMPLICACIONES VASCULARES

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SUMMARY

The number of liver transplants has increased during the last decade and a significant amount of transplants are currently being performed in our country. This trend requires that radiologists have a basic knowledge of the technical aspects of the surgery, as well as its main complications and the imaging criteria used to routinely evaluate grafts. Orthotopic cadaveric donor and living donor transplants are possible at present because of advances in surgical technique, which are based on the understanding of hepatic and vascular surgical anatomy. The most feared complications during the early postoperative period are those of vascular origin, mainly hepatic artery or portal thrombosis, as they can rapidly induce an irreversible damage of the liver graft and hence require immediate medical and/or surgical intervention. Doppler ultrasonography should always be included in the evaluation of the graft during the postoperative period to evaluate the vascular anastomoses periodically and allow a prompt diagnosis of any complication. Therefore, this review includes the main vascular complications after liver transplantation and the fundamental aspects that the radiologist should consider during the routine postoperative evaluation.

RESUMEN

El número de trasplantes hepáticos realizados en nuestro país ha presentado un aumento importante en la última década y actualmente existen centros de trasplante de órganos en varias ciudades del país. Ello exige que el radiólogo posea un conocimiento básico de los aspectos técnicos relevantes durante el procedimiento quirúrgico, sus principales complicaciones y los criterios de éxito según la evaluación hecha. Los avances en las técnicas quirúrgicas permiten llevar a cabo un trasplante hepático con donante vivo mediante la segmentación hepática, además del trasplante ortotópico. Las complicaciones más temidas durante el periodo temprano son aquellas de origen vascular, como la trombosis portal o arterial, ya que rápidamente pueden generar una falla irreversible en el injerto hepático y requieren un manejo médico o quirúrgico inmediato. En la evaluación postoperatoria del paciente trasplantado debe incluirse una ecografía Doppler para valorar el estado de las anastomosis y de esta manera detectar cualquier tipo de complicación. En esta revisión se incluyen las principales complicaciones vasculares y una revisión acerca de los puntos clave en la evaluación ecográfica del injerto en el postoperatorio temprano.

Introduction

Since 1963, when Doctor Thomas Starlz conducted the first successful liver transplant in an adult patient, surgical technique and immunosuppressive therapy has advanced significantly. Liver transplantation is currently considered the best treatment option for chronic liver diseases and acute hepatic failure, with five-year survival rates that reach 70% (1).

Apart from the advances that have occurred in the surgical field, graft conservation and manipulation
techniques have provided a greater availability of viable organs. This progress has permitted the use of liver grafts with certain degrees of steatosis and longer ischemia times, as well as those originating from older donors.

The most common diseases that currently lead to liver transplantation are alcoholic cirrhosis, hepatitis B and C, autoimmune hepatitis, and acute liver failure secondary to other causes (1). Due to the present popularity of liver transplantation and the medical and surgical advances that have occurred in this field, the radiologist must be familiarized with the surgical technique used for each type of procedure, in addition to the most common complications that arise during each phase of the postoperative period. With this in mind, this article’s objectives are: 1) to summarize the surgical anatomy relevant to the radiologist in the postoperative evaluation of the transplanted liver; 2) to go through the characteristic sonographic findings of the most common vascular complications according to the corresponding postoperative period, and 3) to unify the concepts of a routine follow-up ultrasound in these patients.

Basic Principles of Liver Transplantation

Liver transplantation is possible thanks to the ability of the liver to regenerate and to its segmental anatomy. In 1957, Claude Couinaud proposed a division of the liver into independent functional units separated by virtual planes that use real anatomic structures as reference points (the suprahepatic veins and the main branches of the portal vein). These same principles allow for the resection of focal lesions by means of segmentectomies. These same principles have provided a greater availability of viable organs. This progress has permitted the use of liver grafts with certain degrees of steatosis and longer ischemia times, as well as those originating from older donors.

The first liver transplantation was orthotopic and originated from a cadaveric donor. This procedure has been the most frequently applied technique to date, especially in adult patients. During the evolution of surgical technique, live-donor liver transplantation (2-4) by means of the split-liver technique was created. In this new method two to three liver segments are resected (usually segments 2 and 3 or 2, 3 and 4) and are transplanted to the recipient, which leaves the donor with sufficient liver volume for normal functioning. The development of this technique made a greater number of organs available for transplantation, especially in pediatric patients whose donors are most commonly intrafamilial.

The vascular anastomoses performed during liver transplantation are the most important objectives in the postoperative evaluation of recipients. For this reason, the radiologist must be familiar with postsurgical anatomy. The purpose of this article is not to review the different surgical techniques that are currently being employed, yet there are certain basic principles that the radiologist must understand in order to evaluate these patients.

In both the orthotopic transplant and the segmental (split-liver) transplant, the hepatic artery is anastomosed in a termino-terminal manner to the hepatic artery of the recipient. On occasion, anastomoses are performed on more than one arterial branch and it is imperative that the person that carries out the evaluation know this information. Vascular grafts are used when the artery is too short, in order to prevent tension at the site of anastomosis.

The anastomosis of the portal vein is usually termino-terminal between the main portal vein of the donor and the main portal vein, or one of its main branches, of the recipient. The difference between the diameters of the anastomosed vessels can give the appearance of stenosis at the site of anastomosis. Nevertheless, spectral analysis and flow velocities should be the factors that determine an abnormality at these locations, as will be further explained in the upcoming paragraphs.

The anastomosis of the suprahepatic veins to the inferior vena cava is possibly the most technically complex, yet its rate of complications is low (<1%). The procedure used for a cavo-caval anastomosis to the inferior vena cava of the recipient is known as the piggyback technique. In this technique the distal portion of the suprahepatic veins are anastomosed to the recipient’s inferior vena cava. This is currently the most widely used method both in orthotopic and split-liver transplants.

The techniques employed for the anastomosis of the biliary tract are varied, yet a Roux-en-Y choledochojunostomy or a choledochocholedochostomy with a T-tube, in addition to a cholecystectomy, are usually the procedures performed on these patients. The complications of the biliary tract represent the second most common cause of graft dysfunction after rejection.

Routine Postoperative Evaluation

A routine evaluation of the liver graft should be performed in the twelve hours following transplant surgery. At our healthcare facility, Fundación Valle de Lili, an examination is carried out every twelve hours during the first 24 hours, and then every 24 hours depending on the progress of the patient and on medical opinion.

The assessment of the graft has four main objectives: 1) to evaluate the hepatic parenchyma in search of focal lesions due to segmental infarcts or parenchymal hematomas; 2) to look for accumulations surrounding the liver or adjacent to the vascular or biliary anastomoses that may suggest the presence of hematomas, leaks from the biliary anastomoses, or fluid accumulations that can cause a compressive effect; 3) to evaluate the infrahepatic biliary tract and its anastomosis, and 4) to determine the results of the Doppler examination and analyze the arterial and venous vascular structures as well as their anastomoses.

It is important to keep in mind that during the first postoperative hours one might encounter pneumoperitoneum and a small amount of fluid surrounding the liver and in Morrison’s pouch; nevertheless, no organized accumulations of fluid should be identified. In the first 72 hours following surgery, edema of perportal distribution or of the vascular anastomoses may exist and can cause an increase in flow velocities and in resistance indices of the hepatic artery, findings that should be evaluated periodically in order to insure their resolution in the subsequent days (6, 7).

Vascular Complications of Liver Transplantation

Vascular complications represent the third most common cause of liver graft dysfunction. Their incidence is variable and depends on multiple technical factors (8).

Hepatic artery

The biliary tree depends solely on the hepatic artery for its perfusion, thus the importance of evaluating its permeability following transplant surgery, since secondary complications account for 25% of cases of graft dysfunction (9-13).

In the evaluation of the hepatic artery, the radiologist should be informed regarding the type of anastomosis performed on the patient, if vascular grafts were used and whether or not more than one artery was employed to perfuse the graft.

The spectral waveform of the hepatic artery is characterized by a rapid systolic ascent, exhibited by an acceleration time of less than 80 ms, a
peak systolic velocity of less than 200 cm/s and a continuous diastolic flow (9) (Figure 1).

The resistance index (relation between systolic and diastolic velocities) should normally be between 0.6 and 0.7, and values above 0.8 are considered abnormal. Nevertheless, increased resistance indices may be seen in the immediate postoperative period (first 72 hours) due to edema at the site of anastomosis (8, 9, 12, 14, 15).

**Hepatic artery thrombosis** was once the most common complication, especially in the pediatric population, although its incidence has decreased thanks to new microsurgical techniques. However, it continues to be more common in surgeries that use hepatic segmentation (split-liver technique).

The characteristic finding, as is expected, is the absence of blood flow in the hepatic artery. It is possible to find focal abnormalities in the echogenicity of the hepatic parenchyma in cases of arterial thrombosis, which represent ischemic areas with biliary tract compromise.

It is important to adequately characterize the type of waveform that is identified, since there are certain cases of acute transplant rejection and cases of hypotensive patients where one may find normal arterial waveforms of low resistance that may simulate a tardus-parvus waveform (9) (characteristic of arterial stenosis). This waveform may also be seen in intrahepatic branches in cases of chronic arterial thrombosis as a result of slow revascularization by means of collateral circulation.

Hepatic artery stenosis has a reported incidence of 5% to 11% and can present either as an early or as a late complication (9-11). At the same time, this finding is seen more frequently in reduced livers and in cases of prolonged graft ischemia, prolonged use of arterial clamping and in cases of transplant rejection.

Color and spectral Doppler findings of arterial stenosis are characteristic and they must be demonstrated in order to make a correct diagnosis. Figure 2 shows the changes that occur in blood flow and velocity when a vascular stenosis is present. The area of stenosis alters the normal laminar flow of the vessel and causes localized turbulence, which is represented by the aliasing phenomenon on color Doppler.

The spectral waveform proximal to the anastomosis is a normal waveform. At the site of stenosis the peak systolic velocity increases significantly while diastolic flow decreases, which results in an increase in the resistance index. Distal to the site of stenosis, when the vessel reestablishes its normal diameter, it is characteristic to find a tardus-parvus waveform, which is represented by a decrease in peak systolic velocity with a lengthening of the systolic acceleration time and a decrease in the resistance index (RI < 0.5) (8,9).

**Portal Vein**

The portal vein supplies more than 60% of the oxygen required by the hepatic parenchyma. Normal portal flow is affected by the respiratory cycle and therefore shows an oscillating variability in its velocity. The portal vein waveform is monophasic and hepatopetal (1).

In the postoperative evaluation, the identification of the portal vein on grey-scale images is the first step to detecting any possible abnormalities. The vessel lumen should be anechoic. The site of portal anastomosis is recognized as a focal narrowing in the vessel’s diameter and, if possible, should be seen in all patients. In the immediate postoperative period, the vascular anastomosis presents edema that can cause turbulence of blood flow and significant changes in velocity. However, these findings should normalize following the 72 hours after surgery.

After identifying the site of anastomosis (Figure 3), one must measure the flow velocity at the narrowest point in the vessel (anastomosis), proximal to this point (preamastomosis) and distal to it (postanastomosis). The normal flow velocity of the portal vein should be greater than 30 cm/s.

It is common to find an increased flow velocity and turbulence at the site of anastomosis and distal to it, especially during the early postsurgical period (pseudostenosis). Nevertheless, this velocity should not exceed more than three times the velocity found in the preanastomotic segment and it should not be associated with graft dysfunction (Figure 4).

**Portal vein thrombosis** is the complication that arises more frequently in the early postoperative period. The significant difference in diameter of the anastomosed portal vessels is one of the most important predisposing factors for the development of complications (thrombosis or stenosis). At the same time, the technical difficulties encountered in the procedure, the need for vascular grafts, and tortuosity or tension of the anastomosis, increase the risk of developing this complication.

On grey-scale imaging, portal thrombosis is diagnosed by the presence of echogenic material that occupies the vascular lumen either partially or totally (Figure 5). However, recent thrombi may be anechoic and may go unnoticed. Therefore, evaluation with color Doppler is essential because it confirms the partial or total absence of blood flow that may be seen in conjunction with reversed flow in the suprahepatic veins, depending of the time of progression (16, 17).

Portal vein stenosis complicates 2% of transplants and its incidence is also affected by technical factors involving the anastomosis. As was mentioned earlier, an increase of postanastomotic flow velocity greater than three or four times the value of the segment proximal to this area is diagnostic of portal vein stenosis. One typically detects aliasing due to turbulence at the site of lowest diameter of the vessel, and graft dysfunction is a commonly associated clinical finding (18, 19).

**Suprahepatic Veins and Inferior Vena Cava**

The complications involving the suprahepatic (SH) veins and the inferior vena cava (IVC) are infrequent (<1%) and the majority of these consist of acute thrombosis of one or many of these vascular structures. Normal venous flow is hepatofugal and presents a triphasic waveform characterized by an anterograde (which corresponds to atrial contraction) and retrograde (which corresponds to ventricular and atrial diastole) component (Figure 6).

As in portal vein evaluation, grey-scale imaging plays an indispensable role in the detection of intraluminal thrombi in the SH veins and in the IVC. One may frequently find an abnormality in the normal waveform of the SH veins due to the loss of normal distensibility of the hepatic parenchyma because of edema, cholangitis, graft rejection or extrahepatic fluid accumulations. Furthermore, loss of the normal triphasic flow and spectral flattening may also be seen (Figure 7). Moreover, inversion of the direction of blood flow may be seen in portal vein thrombosis. Complete absence of flow determines the presence of thrombosis of the SH veins (1, 20).

**Usefulness of Routine Doppler Evaluation**

Given the importance of early detection of complications that can arise following liver transplant surgery, routine evaluation constitutes
Figure 1. Morphology of a normal waveform characteristic of the hepatic artery. There is a systolic acceleration time of less than 80 ms, a peak systolic velocity of less than 200 cm/s and continuous diastolic blood flow.

Figure 2. Changes in the morphology of the spectral waveform of the hepatic artery according to the evaluated segment in cases of arterial stenosis (prestenosis, stenosis, poststenosis). In the stenotic segment there is a decrease in the systolic acceleration time, a focal increase in flow velocity and a decrease in diastolic flow, with a resulting increase in the resistance index. Distal to the stenosis the systolic acceleration time increases and there is a decrease in the flow velocity, which results in a characteristic tardus-parvus waveform morphology.

Figure 3. Power Doppler image of the main portal vein. The arrow indicates the site of vascular anastomosis. Note the focal change in caliber.

Figure 4. Focal increase in portal vein velocity at the site of anastomosis is shown, in addition to a slight turbulence of blood flow, a finding that is common in the early postoperative period.

Figure 5. Grey-scale and Doppler images. A thrombus that partially occludes the lumen of the main portal vein is shown.

Figure 6. The suprahepatic veins and their anastomosis to the inferior vena cava. There is evidence of hepatofugal flow with a normal triphasic waveform morphology.
Conclusion

The sonographic evaluation of the hepatic graft should be performed routinely during the immediate and early postoperative period in order to detect, in a timely fashion, signs that suggest the presence of potential or established complications.

The radiologist should be familiar with the basic principles of liver transplantation so that he or she may be able to conduct a complete and detailed assessment of the graft, as well as correctly interpret the findings.

The routine evaluation should include the hepatic parenchyma, perihepatic spaces, biliary tract and vascular anastomoses. With the latter, a detailed determination of their permeability and a measurement of their Doppler indices should be performed, keeping in mind that multiple factors can influence the values obtained and, therefore, their meaning should be analyzed together with the functional progress of the transplant.

References


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