The compromised arterial tree : how to deal with ?

J. Fabregat

Unitat de Trasplantament Hepàtic, Hospital Universitari de Bellvitge, L'Hospitalet de Llobregat, Spain.

Abstract

It is accepted that for achieving a successful liver transplantation one of the most important points is the arterial revascularization of the graft. Sometimes de recipient's hepatic artery is not suitable for anastomosis. In this review, we will discuss the different options to deal with a compromised arterial tree in cadaveric orthotopic liver transplantation with whole graft. (Acta Gastroenterol. belg., **2010**, 73, **370-373).**

Key words : Liver transplantation. Arterial conduits. Hepatic artery. Arterial revascularization

It is accepted that for achieving a successful liver transplantation (OLT), the operation must be technically perfect and one of the most important points is the arterial revascularization of the graft. The most common vascular complication after liver transplantation is hepatic artery thrombosis (HAT) which can lead to allograft loss and patient death. The incidence of HAT following liver transplantation varies widely, with a reported frequency of 2.5-9% (1) in adult recipients. Although there are nonsurgical factors associated with HAT (imbalance of the procoagulative and anticoagulative factors, CMV infection, prolonged ischemia and others) probably the most important factor is the result of technical difficulties with the construction of arterial anastomosis. These difficulties may be either due to the presence of hepatic artery variants in the donor and the need of arterial reconstructions on the back table or due to complex arterial anastomosis between donor to recipient artery that are sometimes needed to obtain an optimal inflow to the liver graft. Therefore, a careful management of both the donor's and the recipient's arterial axis is mandatory throughout the operation. In this review, we will discuss the different options to deal with a compromised arterial tree in orthotopic liver transplantation with whole graft and their results. Living related liver transplant and split transplant will not be discussed.

Donor arterial axis

In a substantial number of donor livers (24-32%) variant or anomalous arterial anatomy is present. If an accessory artery is present it has to be reconstructed on the bench to get a single donor artery to be anastomosed in the recipient. Different options of reconstructions have been proposed for particular anomalies. A large accessory right hepatic artery from the superior mesenteric artery is usually reconstructed with an end to end anastomosis to the gastroduodenal or splenic stump. Large left accessory arteries are preserved in continuity with the left gastric artery.

Previous reports have noted an increased incidence of arterial complications when donor variant arterial anatomy and need of reconstruction were present (1-3), although more recent data (4,5) and personal experience (6) suggest no difference.

Recipient arterial axis

To avoid early hepatic arterial complications, which ultimately require a liver retransplantation, a patent arterial anastomosis in the recipient is mandatory.

Standard arterial anastomosis

The preferred method for standard arterial reconstruction was initially a direct anastomoses between donor and recipient HA in end to end fashion (7). Whenever possible it should be carried out using the aortic Carrel patch, because arterial anastomosis without patches were associated with a higher incidence of HAT (7,8). However the use of the celiac-hepatic trunk with a Carrel patch in some instances produces a redundant reconstruction that would seem to be prone to kinking and arterial complications. An alternative method was introduced to improve the results, known as the branch-patch technique (9) ; this uses the bifurcations of the donor and recipient arteries (bifurcation of the common HA to the proper HA and gastroduodenal artery or bifurcation of the proper HA to the left and right HA). The suture of the external crown of the anastomosis prevents affectation of the arterial lumen and permits a good intima-intima apposition. Liver allograft arterialization using branch-patch anastomosis has been the technique of choice and some experiences have shown a significant reduction in thrombosis compared with the end-to-end anastomosis (10). The application of the branch-patch technique in a suitable artery bifurcation from the

Correspondence to : J. Fabregat, Unitat de Trasplantament Hepàtic Hospital Universitari de Bellvitge, C/ Feixa Llarga s/n, 08907 L'Hospitalet de Llobregat, Spain. Tel : +34 932607940. Fax : +34 932607603. E-mail : jfabregat@bellvitgehospital.cat

Submission date : 16/04/2010
Acceptance date : 16/04/2010

donor and recipient to adequate diameter and length of the arterial reconstruction, would reduce the risk of arterial complications (11,12). Running or interrupted sutures of 6-0 or 7-0 polypropylene can be used for arterial anastomosis, some studies suggested that the interrupted sutures technique has a lower incidence of HAT (13).

Unsuitable or inadequate recipient hepatic artery

In some cases the standard arterial reconstruction to the recipient hepatic artery is not possible because of inadequate recipient arteries as a result of thrombosis, atherosclerosis, intimal dissection, small and multiple arteries or other pathology. In such instances, alternative methods of arterialization of the graft have been developed, to achieve an optimal inflow through a widely patent anastomosis from the best possible source. The most popularized are the extra-anatomic arterial reconstructions using aortohepatic conduits and the use of the recipient's splenic artery.

Revascularization to the recipient's splenic artery : In 1992, Figueras *et al*. described the first case of revascularization of the liver graft from the recipient's splenic artery, in a man that underwent a second liver transplantation due to a hepatic artery thrombosis (14). In this procedure the splenic artery is exposed by reflecting the stomach downward through the gastrohepatic omentum and incising the retroperitoneum at the upper edge of the proximal pancreas body. Usually, in the cirrhotic patient with splenomegaly, the splenic artery is dilated, tortuous and can be easily encircled and clamped, the distal end is ligated and divided 3 to 4 cm from the celiac trunk. The proximal end of the splenic artery is turned to the right and an end-to-end anastomosis is performed with the celiac trunk of the donor (Fig. 1). In cases with discrepancy of the diameter between the donor celiac trunk and recipient splenic artery an end to side anastomosis can be done. Spleen vascularization is supplied from the short gastroesplenic vessels and the left gastric artery.

Five years later the same author reported the experience with 23 OLT, eight of them had received a second graft (15). No pancreatitis, splenic infartion or other related complications were found. With a median follow-up of 18 month no arterial complications were reported. One and three years graft actuarial survival were 78% and 72 %. Cherqui *et al*. reported similar results, concluding that arterialization of hepatic grafts using the recipient proximal splenic artery is a simple, safe, and efficient technique that can be recommended in the presence of an inadequate recipient hepatic arterial flow (16). Experimental data have shown that the immunological function of the spleen is preserved after ligature of the splenic artery (17). This technique is feasible in the majority of cases and is particularly suitable in cirrhotic patients with splenomegaly.

Aortohepatic conduits : This is an important tool in the armamentarium of the liver transplant surgeon, and are almost as old as the procedure itself, having first been developed in the laboratory and then applied in the clinic (18-20). It was recognized that arterial inflow to the allograft could only be obtained in some circumstances, with the use of vascular conduits. Donor iliac artery has become the conduit of choice ; if the donor iliac artery is not available some authors recommended use of prosthesic jump grafts (21). The use of cryopreserved grafts as the conduit has been abandoned, because of the high complications rate (stenosis and aneurysm formation) (22). The use of aortohepatic conduits has been reported as being required in 2-32% of adults OLT (15,23-29).

Fig. 1. — Anastomosis of the donor hepatic artery to recipient's splenic artery.

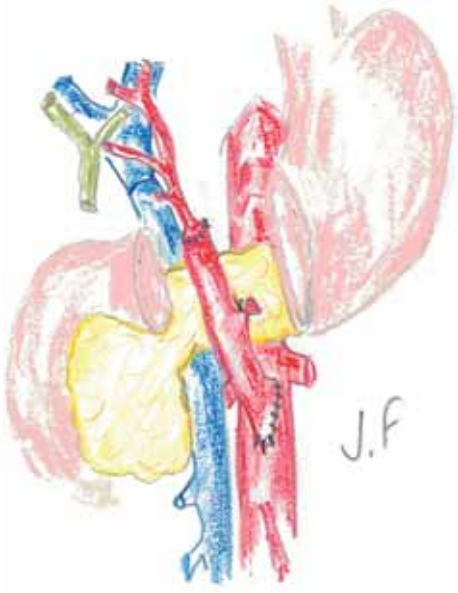

Fig. 2. — Retropancreatic aortohepatic conduit from the infrarenal aorta.

The infrarenal aorta is the preferred site to obtain arterial inflow for vascular conduits ; in most cases the anterior or antepancreatic route is used (30,31). The colon is reflected cranially and the small bowel to the right, opening the peritoneum to the left from Treitz angle, to identify and to expose the infrarenal aorta. A side clamped anastomosis is performed between the aorta and the conduit by means a 4/0 or 5/0 running polypropylene suture. Subsequently, the graft is moved behind the stomach, in front of the pancreas, to the lesser sac through the transverse mesocolon. A self-retaining clamp is applied to the conduit and the aortic clamp is removed from the aorta and any leaks are controlled. Then, the anastomois is performed between the conduit and the donor hepatic artery, usually by the Carrel patch, using 6/0 or 7/0 polypropilen suture (Fig. 2). After completion of the anastomosis, the clamps are removed and the arterial flow in the liver is restored. Typically, this procedure is made after portal reperfusion of the graft, at that time the aortic dissection is somewhat easier because portal hypertension is decompressed and the coagulopathy is being corrected.

Two studies indicated that use of donor arterial conduits was associated with excellent results at short and mean follow-up, without increasing the morbidity, mortality, length of stay or the incidence of thrombosis (26,29). But, some experiences have reported an increase in HAT and a high operative mortality in OLT that required an arterial conduit, but in most cases they were performed for high-risk recipients (re-OLT with and without HAT and emergency reconstructions because infected or ruptured HA aneurysm) in a technical demanding procedure (23,25,28).

Recently, Nikitin *et al.* have reported the first study in the literature on the long-term (up to 20 years) results of aortohepatic conduits in a series of 2346 adult liver transplants. They compared a group of 149 firsts transplants with aortohepatic conduits versus other firsts transplants. Recipients who received conduits had a smaller body mass index and a higher Model of End Stage Liver disease (MELD) score. The use of aortohepatic conduits was associated with longer operative time, more transfusion and more renal failure. There was no difference in graft survival, patient survival, hepatic artery complications or biliary complications between the conduit group and the control group up to 20 years follow up. They observed a trend of lower survival in the first 5 years that may be related to a sicker recipient population (higher MELD). A separate analysis was conducted for retransplants and also was no difference in the long term follow-up (27). These excellent results proves the longevity of aortohepatic conduits using the iliac artery of the donor.

If there are retroperitoneal varices that make the dissection dangerous or if the aorta is severely calcified the conduit could be anastomosed to the right iliac artery. Rare complications are described related to this procedure, such as chylous ascites and acute pancreatitis.

The supraceliac anastomosis was described by Shaked *et al*., exposure of the supraceliac aorta is relatively easy and safe. The muscular fibers of the diaphragmatic crura are split and the anterior and lateral aspects of the aorta are dissected. A side-bitting vascular aortic clamp is then applied for partial occlusion. An aortic Carrel patch of the donor celiac axis is used to create an end to side anastomosis to the aorta. An aortic Carrel patch of the donor common hepatic artery can be anastomosed directly to the aorta. When direct anastomosis is not possible, a short segment of iliac artery graft to the supraceliac aorta is placed (32). The authors described 45 liver transplantations with inadequate hepatic artery in which the supraceliac aorta was used for arterial reconstruction. Direct anastomosis was achieved in 50% of cases and in the others a short segment of the donor iliac artery was required. The incidence of arterial thrombosis and graft loss were zero per cent in adults and 13 per cent in children. They argue that the infrarenal aortic graft usually is relatively long (10 cm) and directed superiorly. This anomalous anatomic orientation and the risk of kinking due to its length, could therefore be the cause of the higher incidence of arterial thrombosis with this approach.

Conclusions

There is no a standard technique for hepatic artery reconstruction because of a variety of arterial length, caliber and anatomic anomalies in both the donor and the recipient. To prevent an HAT an accurate surgical procedure contributing to the optimal vessel matching, using the branch-patch procedure in a suitable bifurcation, to make a short, straight and tension free anastomosis to prevent kinking is the best recommended technique.

In case of inadequate hepatic artery, if the splenic artery has a good caliber and is easily accessible, probably is the best option to vascularize the new liver. If the splenic artery is not a good option, the supraceliac anastomosis, if possible without interposition graft is recommendable. But in the case of difficulties to perform one of these options, as in the case of retransplantation when the adhesions make it difficult, the approach of choice is the infrarenal aorta, with the use of the iliac graft.

The number of retransplantations is growing and this is one of the reasons for the more frequent use of conduits grafts. In spite of that the use of arterial grafts have been associated in some experiences with a lower patient survival and a higher rate of HAT, there is no doubt that thousands of patients have been saved because of the aortohepatic conduits, because there was the unique option to vascularize the liver graft.

References

1. MÜLLER S.A., SCHMIED B.M., MEHRABI A., WELSCH T., SCHEMMER P., HINZ U., WEITZ J., WERNER J., BÜCHLER M.W.,

SCHMIDT J. Feasibility and effectiveness of a new algorithm in preventing hepatic artery thrombosis after liver transplantation. *J. Gastrointest. Surg*., 2009, **133** : 702-712.
2. SOLIMAN T., BODINGBAUER M., LANGER F., BERLAKOVICH G.A., WAMSER P., ROCKENSCHAUB S., MUEHLBACHER F., STEININGER R. The role of complex hepatic artery reconstruction in orthototopic liver transplantation. *Liver Transpl*., 2003, **9** : 970-975.
3. DUFFY J.P., HONG J.C., FARMER D.G., GHOBRIAL R.M., YERSIZ H., HIATT J.R., BUSUTTIL R.W. Vascular complications of orthotopic liver transplantation : experience in more than 4.200 patients. *J. Am. Coll. Surg*., 2009, **208** : 896-903.
4. SETTMACHER U., HAASE R., HEISE M., BECHSTEIN W.O., NEUHAUS P. Variations of surgical reconstruction in liver transplantation depending on vasculature. *Langenbeck's Arch. Surg*., 1999, **384** : 378-383.
5. ABOULJOUD M.S., KIM D.Y., YOSHIDA A., ARENAS J., JERIUS J., MALINZAK L., RAOUFI M., BROWN K.A., MOONKA D.K. Impact of aberrant arterial anatomy and location of anastomosis on technical outcomes after liver transplantation. *J. Gastrointest. Surg*., 2005, **9** : 672-678.
6. LLADO L., FABREGAT J., RAMOS E., *et al.* Variantes arteriales en los donantes hepátcos : ¿influencia en las complicaciones arteriales postrasplante? *Gastroenterología y Hepatología*, 2009, **32** : 10.
7. TODO S., MAKOWKA L., TZAKIS A.G., MARSH J.W. Jr, KARRER F.M., ARMANY M., MILLER C., TALLENT M.B., ESQUIVEL C.O., GORDON R.D., *et al*. Hepatic artery in liver transplantation. *Transplant. Proc*., 1987, **19** : 2406-2411.
8. MERION R.M., BURTCH G.D., HAM J.M., TURCOTTE J.G., CAMPBELL D.A. The hepatic artery in liver transplantation. *Transplantation*, 1989, **48** : 438-443.
9. QUIÑONES-BALDRICH W.J., MEMSIS L., RAMMING K., HIATT J., BUSUTTIL R.W. Branch patch for arterialization of hepatic grafts. Surg. Gyn. Obst., 1986, **162** : 488-499.
10. MENEU-DIAZ J.C. , MORENO-GONZALEZ E., GARCIA GARCIA I., JIMENEZ ROMERO C., LOINAZ SEGUROLA C., GOMEZ SANZ R., PROPOSITO D., ELOLA-OLASO A.M. Hepatic allograft arterialization by means of the gastroduodenal bifurcation (branch patch) as a prognostic factor. *Transplantation*, 2004, **77** : 1513-1517.
11. LORENZIN D., ADANI G.L., COMUZZI C., SAINZ-BARRIGA M., BENZONI E., BRESADOLA V., RISALITI A., BACCARANI U., DE ANNA D. Comparison of two techniques of arterial anastomosis during adult cadaveric liver transplantation. *Transpl. Proc*., 2007, **39** : 1879-1880..
12. JAIN A., COSTA G., MARSH W., FONTES P., DEVERA M., MAZARIEGOS G., REYES J., PATEL K., MOHANKA R., GADOMSKI M., FUNG J., MARCOS A. Thrombotic and nonthrombotic hepatic artery complications in sdults and childrean following primary liver transplantation with long-term follow-up in 1000 consecutive patients. *Transpl. Int*., 2006, **19** : 27-37.
13. COELHO G.R., LEITAO A.S., Jr, F.P., CAVALCANTE BRASIL I.R., CESAR-BORGES G., COSTA P.E., BARROS M.A., LOPES P.M., NASCIMENTO E.H., DA COSTA J.I., VIANA C.F., ROCHA T.D., VASCONCELOS J.B., GARCIA J.H. Continuous versus interrupted suture for hepatica artery anastomosis in liver transplantation : differences in the incidence of hepatica artery thrombosis. *Transpl. Proc*., 2008, **40** : 3545-3547.
14. FIGUERAS J., JAURRIETA E., SEGURA R., RAFECAS A., FABREGAT J., SABATE A., FRADERA R., TORRAS J. A simplified technique for hepatic revascularization of the liver graft with inadequate recipient hepatic artery. *Transplant. Int*., 1992, **5** : 120-122
15. FIGUERAS J., PARÉS D., ARANDA H., RAFECAS A., FABREGAT J., TORRAS J., RAMOS E., LAMA C., LLADÓ L., JAURRIETA E. Results of using the recipients splenic artery for arterial reconstruction in liver transplantation in 23 patients. *Transplantation*, 1997, **64** : 655-658.
16. CHERQUI D., RIFF Y., ROTMAN N., JULIEN M., FAGNIEZ P.L. The recipient splenic artery for arterialization in orthotopic liver transplantation. *Am. J. Surg*., 1994, **167** : 327-330
17. SCHWALKE M.A., CROWLEY J.P., SPENCER P., METZGER J., KAWAN M., BURCHARD K.W. Splenic artery ligation for splenic salvage : clinical experience and immune function : *J. Trauma*, 1991, **31** : 385-388.
18. STARZL T.E., PUTMAN C.W. Experience in hepatic transplantation. Philadelphia, PA : Saunders, 1969 : 129-133.
19. STARZL T.E., HALGRIMSON C.G., KOEP L.J., WEILL R., TAYLOR P.D. Vascular homografts from cadaveric organ donors. *Surg. Gyn. Obst*., 1979, **149** : 737.
20. SHAW B.W. Jr, IWATSUKI S., STARZL T.E. Alternative methods of arterialization of the hepatic graft. *Surg. Gynecol. Obstet*., 1984, **159** : 490-493.
21. JOVINE E., MAZZIOTI A., ERCOLANI G., MASETTI M., MORGANTI M., PIERANGELI F., BEGLIOMINI B., MAZZETTI P.G., ROSSI R., PALADINI R., CAVALLARI A. Prosthesis jump graft : An unusual arterial reconstruction in liver transplantation. *Transplantation*, 1998, **65** : 288-290.
22. KUANG A.A., RENZ J.F., FERRELL L.D., RING E.J., ROSENTHAL P., LIM R.C., ROBERTS J.P., ASCHER N.L., EMOND J.C. Failure patterns of cryopreserved vein grafts in liver transplantation. *Transplantation*, 1996, **62** : 742-7.
23. MURALIDHARAN V., IMBER C., LEELAUDOMLIPI S., GUNSON B.K., BUCKELS J.A., MIRZA D.F., MAYER A.D., BRAMHALL S.R. Arterial conduits for hepatic artery revascularisation in adult liver transplantation. *Transpl. Int.*, 2004, **17** : 163-168.
24. SANSALONE C.V., COLELLA G., RONDINARA G., ROSSETTI O., DE CARLIS L., BELLI L.S., MERONI A., DELLA VOLPE A., TROJSI C., BELLI L. Iliac artery graft interposition in liver transplantation : our experience in 72 cases. *Transplant. Proc.*, 1994, **26** : 3535-3536.
25. LIU T., DILWORTH P., SOSEF M., WANG C., CRAWFORD M., GALLAGHER J., VERRAN D. Arterial vascular conduits in adult orthotopic liver transplant recipients. *ANZ J. Surg*., 2006, **76** : 64-67.
26. ZAMBONI F., FRANCHELLO RICCHIUTI A., FOP F., RIZZETTO M., SALIZZONI M. Use of arterial conduit as an alternative technique in arterial revascularization during orthotopic liver transplantation. *Digest. Liver Dis*., 2001, **33** : 122-126.
27. NIKITIN D., JENNINGS L.W., KHAN T., VASANI S., RUIZ R., SANCHEZ E.Q., CHINNAKOTLA S., LEVY M.F., GOLDSTEIN R.M., KLINTMALM G.B. Twenty years of follow-up of aortohepatic conduits in liver transplantation. *Liver Transpl.*, 2008, **14** : 1486-1490.
28. DEL GAUDIO M., GRAZI G.L., ERCOLANI G., RAVAIOLI M., VAROTTI G., CESCON M., VETRONE G., RAMACCIATO G., PINNA A.D. Outcome of hepatic artery reconstruction in liver transplantation with an iliac arterial interposition graft. *Clin. Transplant.*, 2005, **19** : 399-405.
29. CAPPADONA C.R., JOHNSON L.B., LU A.D., KUO P.C. Outcome of extra-anatomic vascular reconstruction in orthotopic liver transplantation. *Am. J. Surg*., 2001, **182** : 147-150. *Transplantation*, 1996, **62** : 742-7.
30. TZAKIS A., TODO S., STARZL T.E. The anterior route for arterial graft conduits in liver transplantation (letter to the editor). *Transpl. Int*., 1989, **2** : 121.
31. GOLDSTEIN R.M., SECREST C.L., KLINTMAN G.B., HUSBERG B.S. Problematic vascular reconstruction in liver transplantation. Part I. *Arterial. Surgery*, 1990, **107** : 540-543.
32. SHAKED A.A., TAKIFF H., BUSUTTIL R.W. The use of the supraceliac aorta for hepatic arterial revascularization in transplantation of the liver. *Surg. Gynecol. Obstet*., 1991 : **173** : 198-202.