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ORIGINAL ARTICLE

Arterial reconstruction in rat liver transplantation – development of a new tubing technique of the common hepatic artery

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Summary

Arterialization of liver transplants in rats results in an improved function compared with grafts without artery. Here we compared techniques of reconstruction, focusing on thrombosis, duration of procedure and severity of pancreas damage after dissecting the gastroduodenal artery (GDA). Group 1: tube was inserted into the proper hepatic artery (PHA) of donor and recipient. Group 2: tube was placed into common hepatic artery (CHA) of donor and recipient. Group 3: cuff was placed over the CHA of the recipient and the graft's artery was slipped over the cuff. Tubing in PHA leads to a thrombosis rate of 40% after 6 months. Arteries remain perfused by using a cuff or tube in CHA. Dissection of the GDA does not influence pancreatic perfusion. Reconstruction took 19 s using the large tube, about 30 s for the tube into PHA and 1 min for the cuff. The method of choice is using a tube for the CHA.

Introduction

In the rat model of orthotopic liver transplantation, arterialization of the grafts has been favored in order to preserve the integrity of the bile duct system and the hepatic architecture [1]. In addition, arterialized rat liver transplants show tremendous benefits compared with nonarterialized regarding survival after prolonged cold storage [2], antigen presentation [3], and microcirculatory disturbances [4]. However, in some studies it has been shown that arterial reconstruction might be an unnecessary procedure of the microsurgical operation [5,6]. In contrast, the marked differences stated above demonstrate that arterial reconstruction in the rat should definitely not be omitted. Moreover, it has clearly been shown that simultaneous arterial and portal venous reperfusion improves graft function and reduces ischemia/reperfusion injury in comparison with delayed arterial reperfusion [7].

Various techniques have been developed to establish hepatic rearterialization in rat liver transplantation. First publications describe harvesting a donor aortic segment with an end-to-side anastomosis of donor aorta to recipient aorta [3], a cuff anastomosis to the renal artery after nephrectomy [8], ligation of the gastroduodenal artery (GDA) with cuff anastomosis to the common hepatic artery (CHA) [9], connecting the proper hepatic artery (PHA) of donor and recipient with a splint of polyethylene tubing [2] and the microvascular sleeve anastomosis in rat liver transplantation [10], which has recently been modified to simplify the procedure [11].

Several concerns have been raised with each individual technique: aortic end-to-side anastomosis means a very long operation time for this single step, manual manipulation in the abdomen of the recipient and temporary reduced blood flow associated with warm ischemia inferior to the anastomosis. Therefore, in our opinion microsurgeons should not perform this technique anymore. Unilateral nephrectomy means postoperative morbidity and alteration of physiologic fluid and electrolyte balances. Therefore, this technique should definitely be avoided in recipients in order to establish almost physiological conditions after transplantation as soon as possible. Concerns have been raised about the cuff technique in the CHA of the recipient because it might be associated with damage of the pancreas after ligation of the GDA and in addition, this technique might take a relatively long operation time. Moreover, it could also lead to manipulation in the abdomen of the recipient. Implanting a tube in the PHA of donor and recipient might result in thrombosis of this tube and therefore sufficient rearterialization would not be established. The technique of sleeve anastomosis seems to be reliable and sufficient but a mean operation time of 7.8 min [11] in association with significant manipulation is not acceptable and not practical in our opinion. Moreover, a procedure taking 5–12 min in the recipient [11] does not always allow a simultaneous reperfusion of arterial and portal venous blood flow. Consequently we would not recommend performing this technique.

In summary, several techniques to reestablish arterial blood flow in rat liver transplantation have been developed. However, all methods are characterized by some positive and important negative aspects and no optimal procedure without serious disadvantages has been described so far. The purpose of this study was to introduce a very simple and fast procedure and to compare three acceptable techniques concerning occlusion rate, operation time and damage of the pancreas.

Materials and methods

Animals and treatment

All animals received humane care according to the criteria outlined in the 'Guide for the Care and Use of Laboratory Animals' (NIH publication 86–23, revised 1985). Experiments were performed in accordance with protocols approved by the Animal Use Committee of the University of North Carolina. Inbred female Lewis rats (180–210 g) obtained from Charles River (Raleigh, NC) were used for all transplantations to exclude immunologic interference and had free access to standard laboratory chow (Agway PROLAB RMH 3000; Agway Inc. Syracuse, NY) and tap water [12].

Liver transplantation

Both donors and recipients were anesthetized by inhalation with methoxyflurane. Rats were anesthetized and livers were harvested in a standardized manner within 7–8 min as described elsewhere [13]. Livers were perfused with 10 ml of ice-cold Ringer's solution followed by perfusion with 5 ml of cold University of Wisconsin (UW) storage solution (ViaSpan®; DuPont Pharma, Wilmington, DE, USA) via the portal vein. Cuffs were attached in the cold to the infrahepatic vena cava and portal vein, and livers were stored in UW solution at 4 °C for 24 h. Recipient rats were anesthetized and orthotopic liver transplantation was performed including reconstruction of the artery as described below. Grafts were rinsed with 10 ml of lactated Ringer's solution (4 °C) and implanted by connecting the suprahepatic vena cava with a running 7/0 Prolene® (Ethicon Gmbtt, Norderstedt, Germany) suture, inserting cuffs into the corresponding vessels and anastomosing the bile duct. Implantation surgery required approximately 34 min including 12 min when the portal vein, vena cava and CHA were clamped. Arterial and portal venous reperfusions were always performed simultaneously. After transplantation, recipients had free access to standard laboratory chow and tap water.

Arterial reconstruction

Group 1

In the donor the PHA was carefully liberated from the portal vein without touching or manipulating the liver or other organs. No vessels were ligated or dissected. After flushing the liver *in situ* with UW solution the CHA was dissected proximal to the gastric and splenic arteries in order to have a long CHA/celiac artery. After removing the organ of the body the liver was prepared in the 'backtable' operation and a polyethylene splint of 4 mm length (PE 10, inside diameter 0.28 mm, outside diameter 0.61 mm; BD Clay Adams, Sparks, MD, USA) was washed with 100 IU heparin in Ringer's solution, inserted into the PHA and secured with a 6-0 silk suture [2]. In recipients, prior to removal of the 'old' liver, the PHA was dissected and ligated with a 6-0 silk suture close to the entrance into the liver segments. Livers were implanted into the recipient by connecting the suprahepatic vena cava and inserting the cuffs into the appropriate vessels. Using an operation microscope, the recipient's PHA was opened, washed with 100 IU heparin in Ringer's solution and anastomosed by inserting the splint, which was secured with a 6-0 silk suture. Arterial and portal venous clamps were removed simultaneously.

Group 2

In the donor, the PHA was carefully liberated from the portal vein without touching or manipulating the liver or other organs. No vessels were ligated or dissected. After flushing the liver *in situ* with UW solution the CHA/celiac artery was dissected close to the aorta, proximal to the gastric and splenic arteries in order to have a long CHA/celiac artery. After removing the organ of the body the liver was prepared in the 'backtable' operation and a polyethylene splint of 4 mm length (Becton Dickinson Insyte^{TM} i.v. catheter 24G, inside diameter 0.51 mm, outside diameter 0.7 mm; Becton Dickinson, Franklin Lakes, NY, USA) was washed with 100 IU heparin in Ringer's solution and inserted into the CHA and secured with a 6-0 silk suture (Fig 3). In recipients, prior to removal of the 'old' liver, the PHA as well as the GDA were dissected and ligated with a 6-0 silk suture close to bifurcation of the CHA. The CHA was clamped using a microsurgery vessel clip. Livers were implanted into the recipient by connecting the suprahepatic vena cava and inserting the cuffs into the appropriate vessels. Using an operation microscope, an incision was cut into the bifurcation. Then, the splint in the donor CHA was inserted into the recipient's CHA and secured with a 6-0 silk suture. Arterial and portal venous clamps were removed simultaneously.

Group 3

This procedure was performed as described by Steffen *et al.* [9] and modified by Post *et al.* [4]. Briefly, in the donor again the PHA was carefully liberated from the portal vein without touching or manipulating the liver or other organs as well. No vessels were ligated or dissected. After flushing the liver *in situ* with UW solution the celiac artery was dissected including the aortic segment where the celiac artery originates. After removing the organ of the body, the liver was prepared in the 'backtable' operation and all branches of the CHA/celiac artery were occluded by a 6-0 silk suture. The aortic segment was prepared as a vascular shoe. In recipients, prior to removal of the 'old' liver, the PHA as well as the GDA were dissected and ligated with a 6-0 silk suture 3 mm distant to bifurcation of the CHA. The CHA was clamped using a microsurgery vessel clip. The cuff at the CHA (made of a Becton Dickinson Insyte^{TM} i.v. catheter 24G, inside diameter 0.51 mm, outside diameter 0.7 mm) was mounted before hepatectomy to minimize the time required for arterial anastomosis during the anhepatic phase. Livers were implanted into the recipient by connecting the suprahepatic vena cava and inserting the cuffs into the appropriate vessels. Using an operation microscope, the aortic segment of the donor's celiac artery was slipped over the recipient's arterial cuff and secured with a 6-0 silk suture. Arterial and portal venous clamps were removed simultaneously.

The time used for each step of the whole operation was exactly measured in every animal, donors and recipients. Animals were killed 8 h, 24 h and 6 months after reperfusion to evaluate occlusion rates of the reconstructed arteries. Serum amylase and lipase as well as histology were evaluated in animals which were killed 24 h after reperfusion.

Histological procedures and clinical chemistry

Histology was evaluated 24 h after transplantation. Pancreatic, hepatic and bile duct tissues were fixed by immersion in 10% buffered formalin, embedded in paraffin, and processed for histology. Tissue damage was assessed in hematoxylin and eosin-stained sections (4 μm) by estimating the proportion of necrotic to non-necrotic areas as described elsewhere [14]. Briefly, five fields (100× magnification) were selected at random from at least four different sections per sample, and mean values were calculated. Histologic examination was performed in a blinded manner.

Blood samples to measure pancreatic amylase and lipase were collected from the inferior vena cava 24 h after transplantation. At this time point necrotic pancreatitis caused by local ischemia with elevated enzyme levels in serum would be most severe [15]. Serum was obtained by centrifugation and stored at −80 °C until analysis was determined by standard enzymatic methods [16].

Statistics

Mean values ± SEM for various groups were compared using Fisher's exact test or one-way, or two-way ANOVA with Student–Newman–Keuls *post hoc* test as appropriate. $P < 0.05$ was selected prior to the study as the criterion for significance.

In this study three different groups representing different surgical techniques were compared in several aspects. To exclude any effect of training, the technique of rearterialization for each donor and recipient pair was chosen randomly to exclude any effect of training. Randomization was performed as follows: on each day each technique was performed in order to avoid any effect of training on final results. This means that on each day three liver transplantations were performed and each operation was carried out with a different technique of arterial reconstruction. The chronological order in which each operation of each group was performed daily was evaluated by randomization using a random number generator (SigmaStat®; Systat, Point Richmond, CA, USA).

Results

Effects of three different arterial reconstruction techniques on occlusion rate of the hepatic artery

The occlusion rate of the revascularized hepatic artery was examined at three different time points for each technique.

Group 1: small tube in the PHA of donor and recipient

In 20 of 30 examined recipients, the proper hepatic arteries of the donor graft were perfused 8 h after reperfusion. The other ten cases showed a complete thrombosis of the tube and the thrombosis continued into the PHA on the recipient's side. In animals examined 24 h after reperfusion, an identical result was observed: 20 of 30 arteries were perfused and the 10 cases with occluded arteries showed a thrombus in the tube and in the PHA of the donor (Table 1). In animals evaluated 6 months after transplantation we found that 18 of 30 hepatic arteries were perfused (Table 1) and the 12 animals with occluded tubes showed severe pathologic signs of bile duct lesions, intrahepatic abscesses and liver fibrosis (data not shown). These results demonstrate that a small tube (inside diameter 0.28 mm) inside the PHA of donor and recipient means a high risk of vascular occlusion of the artery. Moreover, vascular occlusion of the tube in the PHA usually occurs within the first hours after reperfusion.

Group 2: larger tube in the CHA of donor and recipient

In this group no vascular occlusion was observed at any time point studied, all hepatic arteries remained perfused (Table 1). Consequently, in all transplanted animals examined 6 months after transplantation any liver pathology representative for arterial occlusion like cholestasis, bile duct necrosis, liver fibrosis was absent (data not shown). The results clearly demonstrate that a relatively large tube inside the CHA, designed for the *in vivo* use in vessels does not lead to any thrombosis under the conditions in this artery of a rat.

Group 3: cuff technique in the CHA of donor and recipient

Again, in this group all arteries remained perfused at the three time points studied (Table 1). Moreover, 6 months after transplantation all grafts were intact without any ischemia-related disease or defect. The results show that performing the technique of an endothelialized connection between the arteries of the donor and the recipient eliminates any risk of vascular occlusion. Therefore, the cuff anastomosis of the artery is suitable in rat liver transplantation.

Table 1. Perfusion rates of reconstructed arteries.

	PHA perfused 8 h after reperfusion	PHA perfused 24 h after reperfusion	PHA perfused 6 months after reperfusion
Group 1 (PHA-PHA)	66.7%* (20/30)	66.7%* (20/30)	60%* (18/30)
Group 2 (CHA-CHA)	100% (30/30)	100% (30/30)	100% (30/30)
Group 3 (cuff in CHA)	100% (30/30)	100% (30/30)	100% (30/30)

Perfusion of reconstructed arteries after liver transplantation was determined by relaparotomy and dissection of the artery distal of the anastomosis. An operation microscope was used to investigate possible reasons for occlusion. A significant difference was observed between the results in group 1 compared with the results in group 2 as well as in group 3 for each time point studied, * = $P < 0.005$
In every group 30 recipients were studied, perfusion rate is noted as perfused arteries of all arteries observed (e.g. 20/30) and calculated as percentage (%) of perfused arteries.
PHA, proper hepatic artery; CHA, common hepatic artery.

Time expenditure to perform each technique

In our experience the surgical time required to perform the whole operation is critical for the outcome especially under conditions when marginal grafts or very long storage times (24 h and longer) are used. Moreover, it is essential to allow a simultaneous reperfusion of the portal vein and the hepatic artery. Consequently the arterial

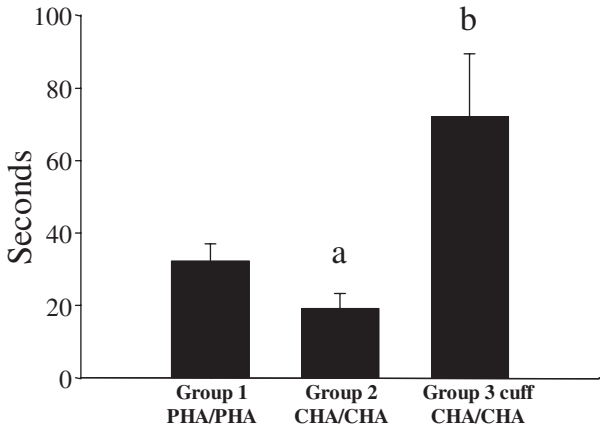

Figure 1 Time expenditure to perform each technique. The time needed to perform each arterial reanastomosis in every recipient has been evaluated in a very large series per group. (Values are mean ± SEM; $n = 90$ in each group). However, implanting a large tube into the common hepatic artery (CHA) of the recipient (group 2) is the fastest procedure of arterial reanastomosis. Implanting a small tube into the proper hepatic artery (PHA) of the recipient is somewhat more time-consuming, and the difference of 14 s is statistically significant [(a) $P < 0.001$ by Fisher's exact test comparing group 2 with group 1]. Performing the cuff technique of arterial reanastomosis takes more than 70 s, the difference between group 1 and group 3 as well as between group 2 and group 3 is statistically significant [(b) $P < 0.001$ by Fisher's exact test comparing group 1 with group 3 as well as group 2 with group 3].

reconstruction should be as fast as possible. In *group 1* the time required to reestablish arterial perfusion was about 32 s ($n = 90$) (Fig. 1). This is the time used to insert the small tube into the corresponding part of the PHA of the recipient. This procedure can be difficult and time-consuming as the incision of recipient's artery is very small and usually needs some dilatation to get the tube placed inside the lumen of the vessel. In contrast, in *group 2* the inside diameter of the CHA artery is relatively wide and the vessel is elastic, the larger tube of 24G is easily inserted with one surgical movement. This is the reason why this procedure usually took <20 s ($n = 90$) (Fig. 1). However, performing the cuff anastomosis took about more than 1 min ($n = 90$) (Fig. 1). This can be explained by the fact that the microvascular clip has to be attached to a mechanical stage to exclude any movement of the cuff over the artery while sliding the donor's artery over the cuff. Two forceps need to be used to slide the donor's artery over the cuff meaning that both hands of the surgeon are in use and cannot hold the cuff. The mechanical stage has to be removed before reperfusion starts. Additionally, the surgeon has to be very precautious that the long donor vessel may not be twisted.

Effects of ligation of the GDA on the pancreas

In groups 2 and 3 the GDA has to be dissected in order to perform the arterial reconstruction using the tube in the CHA or the cuff over the CHA. The GDA remains intact in group 1 when a small tube is placed in the recipient's PHA. Surprisingly, amylase and lipase in serum were almost identical in each group ($n = 30$ per group) 24 h after reperfusion when ischemic damage to the pancreas should be most severe (Fig. 2a and b). In all animals killed 24 h after reperfusion the pancreas was harvested and processed for histology. Mirrored by pancreatic enzyme tests not any necrotic area in the pancreas could be observed in any group (data not shown). These results demonstrate that ligation of the GDA does not harm the perfusion of the pancreas in the rat and no necrosis of the pancreas occurs.

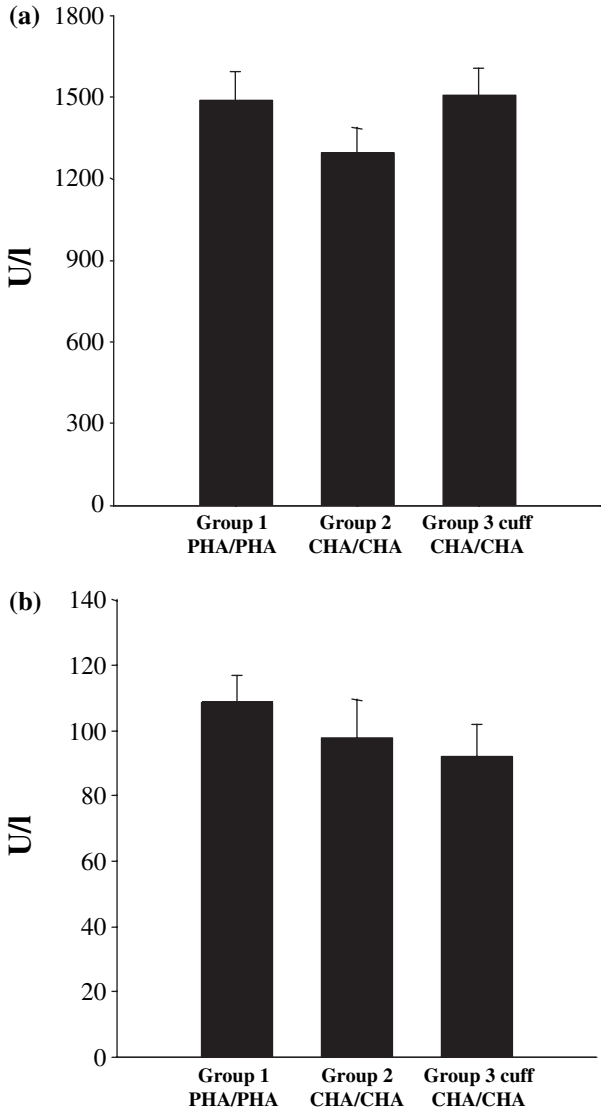

Figure 2 Effects of dissection of the gastroduodenal artery (GDA) on serum amylase (a) and lipase (b). Amylase and lipase activity in serum was measured with standard enzymatic methods 24 h after reperfusion of liver grafts. (Values are mean ± SEM; $n = 30$ in each group). No statistical significant difference could be observed between group 1 with intact GDA and group 2 or 3 with dissected GDA.

Discussion

Under physiological conditions the hepatic artery supplies at least 50% of the oxygen needed by the liver which is essential for producing energy and regulating metabolism [17]. Hepatic artery reconstruction is essential in human liver transplantation. Accidental injury to the hepatic artery is lethal, occlusion of the PHA after liver transplantation in humans often results in the loss of the graft leading to re-transplantation with elevated rates of mortality [18,19]. Injury to hepatic artery branches, which could happen in the clinic during laparoscopic cholecystectomy for example, leads to necrosis or fibrosis of the corresponding liver segments.

In the past it has clearly been demonstrated that arterialization in hepatic transplantation is essential for improving survival [2], reducing microcirculatory disorders [4], avoiding biliary complications [10] and modifying immunologic responses [3]. Although one study indicated that ligation of the hepatic artery did not affect the bile duct after 3 months of liver transplantation in

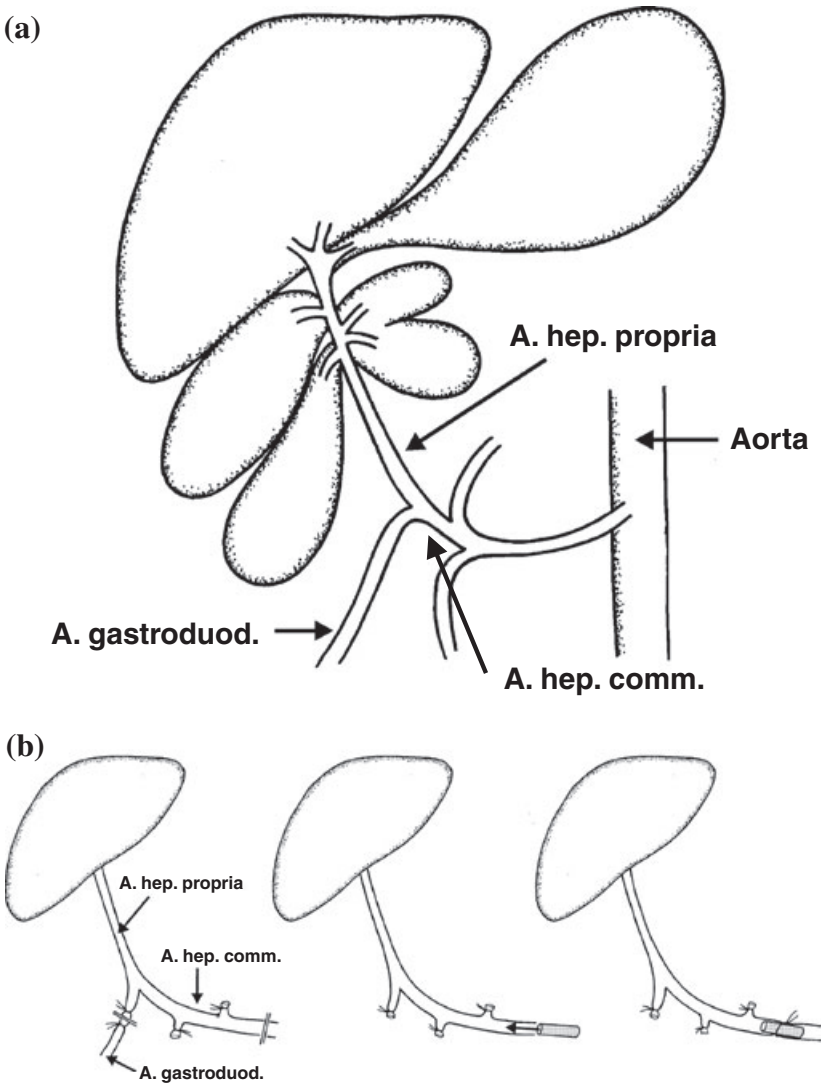

Figure 3 (a) Scheme of the anatomy of the liver in the rat with arterial blood supply. In this scheme the arterial blood supply of the liver of the rat is shown. Note the relatively long proper hepatic artery (A. hep. propria) and the anatomically correct wide angle of approximately 90° between PHA and GDA (A. gastroduodenalis). (b) Scheme of the preparation of the artery of the donor liver. After harvesting the donor liver, all vessels are prepared and cuffs are attached in the cold. Note the ligation of branches of the common hepatic artery and the implantation of a tube into the CHA.

rats [6], all other studies clearly indicate the necessity of rearterialization in order to prevent biliary tree necrosis and complications [8,9]. These observations are in accordance with our own experiences in this study, where only grafts with intact hepatic artery were free of any biliary complications 6 months after transplantation.

The question of the best technique of arterial reconstruction in rat liver transplantation remains controversial although several techniques have been proposed. The best technique should be very fast to perform, no occlusion should occur and no other pathology should be initiated. Now, all questions can be answered and all demands can be fulfilled for the best procedure of arterial reconstruction in the rat.

Occlusion rate

Using a small splint in the PHA of donor and recipient Gao *et al.* have reported an occlusion rate of <10% [20]. Others and we have tried exactly the same technique with the identical tube material in large series and could not report the same low rate of thrombosis (Table 1). To exclude any effect of training, we have performed more than 200 liver transplant procedures for other studies

using the described splint technique before we started to include recipients in this study. Moreover, for each donor and recipient pair, the technique of rearterialization was chosen randomly to exclude any further effect of training while working on this study. Using the splint technique in the PHA in 90 recipients we have observed a significant rate of thrombosis; therefore we cannot recommend this technique. In contrast, thrombosis does not occur when using a larger splint inside the CHA of donor and recipient. In other words, there might be less functional stenosis caused by the tube resulting in a higher perfusion rate. Moreover, the material used is made for routine use in human vessels with very low potential of irritation to the endothelium and the thickness of the wall (0.19 mm) is very small. The surface structure of this material does not seem to induce thrombosis by itself. Performing the cuff technique we have used the same tube material with an inside diameter of 0.51 mm. Again, no vascular occlusion was observed. This result demonstrates that the endothelialized tube does not provide any benefit compared with group 2 (tube in CHA) where the foreign material of the tube remains in the bloodstream. Moreover, the inside diameter is even large enough to perform the cuff technique with the artery inside the tube without having any occlusion because of obstruction by a minimal inside diameter. This means that the inside diameter of 0.51 mm in group 2 is definitely large enough.

Time needed for the operation

As stated above, to exclude any effect of training we have performed large series of all three methods of rearterialization before we included animals in this study. In our experience it is essential to perform the step of reconnecting the hepatic arteries as fast as possible to allow a simultaneous reperfusion of the graft. Moreover, preparation of the artery prior to the anhepatic phase should be as minimal as possible in order to avoid any prolongation of whole procedure and to avoid any further manipulation. Touching, moving and manipulation of the intestine during the implant procedure may lead to pathophysiological reactions resulting in lower survival rates. This is true for manipulation of the liver during the harvest procedure,

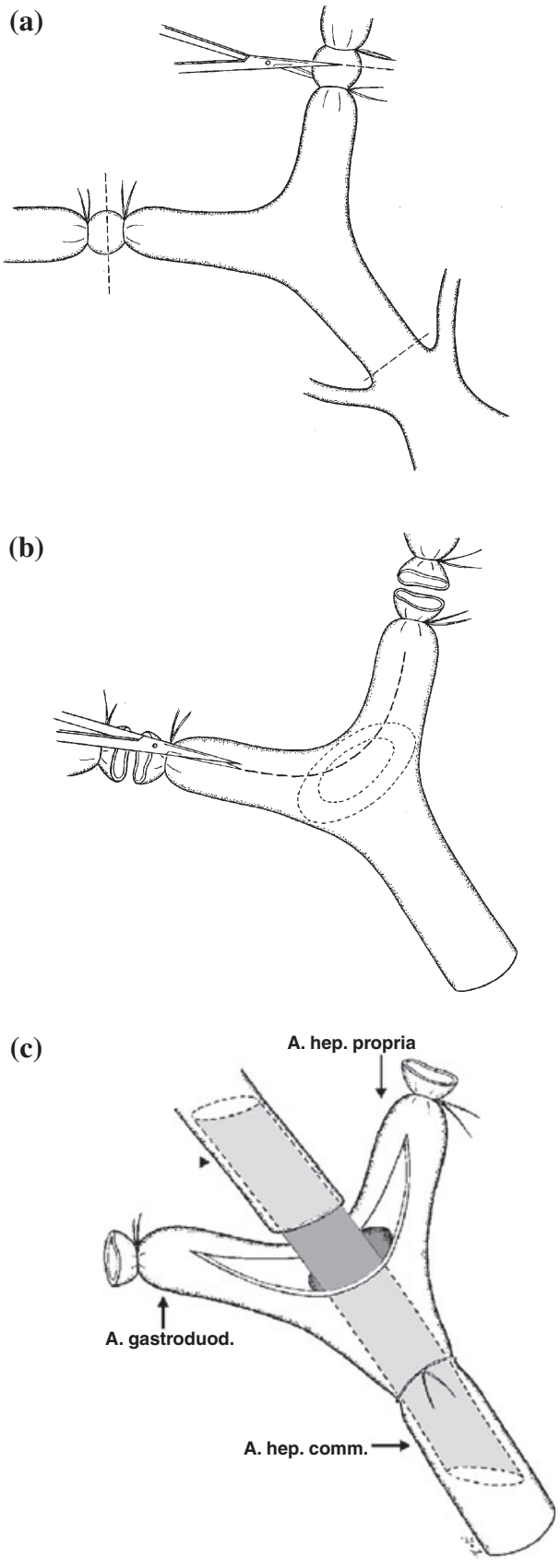

Figure 4 Scheme of the preparation of the CHA in the recipient of the large tube technique: (a) PHA and GDA are ligated and dissected, the distance to the bifurcation is approximately 3 mm each side, a Y-structure at the end of the CHA is created. (b) After ligation and separation of the branches a small incision is made into the concave part of the Y-structure using very small microscissors. (c) The large tube placed in the CHA of the donor is slid into the opening in Y-structure of the CHA and secured with a 6-0 silk loop.

where manipulation leads to reduced survival rates [21]. Preparation of the hepatic artery in the donor is minimal in group 1 (PHA/PHA). In contrast, in group 2 (CHA/CHA) and group 3 (aorta/CHA-cuff) the GDA should be dissected prior to perfusion with storage solution. The separation, ligation and dissection takes <1 min and manipulation can be avoided. In other words, dissection of the GDA in the donor should not induce any problem. In the recipient, preparation of the PHA in group 1 takes <30 s. The PHA has to be separated from the bile duct and the portal vein and has to be dissected close to the liver. In groups 2 and 3, the additional step is to dissect the GDA and to liberate the CHA from soft tissue. This additional procedure takes <1 min in group 2. In group 3 after separation of the CHA with its two branches, GDA and PHA, the tube has to be slid over the vessel. The CHA is occluded with a temporary microvascular clip and the clip is stabilized in the abdomen with a specially designed mechanical stage. In the next step, the cuff has to be prepared and secured. This procedure takes at least another 3 min and additional manipulation of the intestine, stomach and pancreas cannot be avoided. In summary, the cuff technique is too time-consuming with the disadvantage of additional manipulation. Implanting the arterial tube during the anhepatic phase is usually not a problem in group 1. In most cases the artery has to be widened with the tip of a microvascular forceps in order to place the tube inside the artery. In group 2 the procedure is very simple as displayed in the instruction figure (Fig. 4), a small cut has to be made between PDA and GDA, a wide opening is visible and the large tube can easily be placed inside the CHA. In group 3 the clip has to be secured again using the mechanical stage and then the aortic segment can be slid over the cuff. Special attention is needed for avoiding any twisting of the donor artery. The mechanical stage has to be removed prior to reperfusion. The procedure takes more than 1 min, it is more time-consuming than the other two procedures. Consequently, we would not recommend the cuff technique as the other techniques are significantly faster to perform.

In the past, ligation of the GDA of the recipient is reported to lead to necrosis of the pancreas and necrosis of the bile duct [9]. Gao *et al.* reported that bile leakage occurred with a frequency of about 30% when ligation of the GDA was performed. Wrapping momentum above the necrotic bile duct would prevent bile leakage but would result in internal fistules [2]. However, in this study, in group 2 as well as in group 3 no bile duct necrosis was observed although the GDA was dissected. This can be explained by the fact that the bile duct was not liberated from soft tissue. In the recipient, prior to explantation of the recipient's liver, the bile duct was dissected very close to the entry into the liver lobules. Therefore, the microvasculature responsible for perfusion of the bile duct remains intact. These microvessels are perfused by small arteries branching out of the pancreas and the GDA. When dissecting the GDA the distal part may not be stripped of the soft tissue including microvessels feeding the bile duct microvasculature because a very strong backflow out of this distal part can be observed. Respecting these rules and precautions, bile duct necrosis and bile leakage do not occur. In addition, in the donor the bile duct is dissected close to the bifurcation of the CHA. Surgeons have to be very careful not to separate the bile duct from soft tissue and from the PHA. Otherwise necrosis in the donor's part of the bile duct would occur. In this study pancreas necrosis was not observed in any group, ligation of the GDA did not harm the pancreas. This can be explained by the fact that several arteries perfuse the pancreas and multiple functional anastomoses between GDA, splenic artery and mesenteric artery exist. Strong backflow out of the distal part of the dissected GDA supports this statement. Counting all together ligation and dissection of the GDA in the recipient is not harmful to the animal, the pancreas and the bile duct remains intact.

In summary, the data presented in this study indicate that arterial reconstruction in rat liver transplantation is easy to perform and is not associated with any delay of the whole procedure or with any harmful effect to the recipient. Thrombosis of the artery can be prevented completely and the procedure of reconnection can be carried out within seconds. Taking all aspects into account we would definitely recommend the technique of the tube connecting CHA with CHA as explained in group 2 (Fig. 4) to reestablish arterial perfusion of the graft which meets the needs of research in rat liver transplantation. The other two well established techniques explained in this study show several severe disadvantages and therefore cannot be recommended.

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