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The "W" Technique: A Safe and Reproducible Technique for Hepatic Artery Reconstruction in Living Donor Liver Transplantation

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Data Collection B
Statistical Analysis C
Data Interpretation D
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Background: Reconstruction of the hepatic arterial inflow can be technically demanding in living donor liver transplantation, and thrombosis can result in graft loss and mortality. We describe the safe and reproducible "W" technique to reconstruct the hepatic artery and outcomes before and after adoption of the technique in a consecutive series of liver transplants at 2 high-volume living donor liver transplant centers.

Material/Methods: Prospectively collected data were analyzed to compare the outcomes before and after introduction of a standardized "W" technique for reconstruction of the hepatic artery in 2 high-volume living donor liver transplant programs.

Results: In a consecutive series of 675 liver transplants, of which 27 were deceased donor transplants and 648 were living donor transplants, 443 transplants were performed with a standard interrupted reconstruction of the hepatic artery under loupes. These transplants were performed by a single surgeon, with an incidence of hepatic artery thrombosis of 2%. After introduction of the "W" technique, despite the arterial reconstruction being done by several surgeons in the early part of their learning curve, the incidence of hepatic artery thrombosis decreased to 0.86% in the next 232 transplants.

Conclusions: The "W" technique is a simple, easy to learn and teach technique for reconstruction of the hepatic artery without the use of the operating microscope in living donor liver transplantation.

MeSH Keywords: **Hepatic Artery • Liver Transplantation • Living Donors**

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Background

Reconstructing arterial inflow is one of the more demanding and crucial steps in liver transplantation. Thrombosis of the hepatic artery may lead to necrosis of the liver graft or, more insidiously, to intractable biliary complications and graft failure, which can lead to retransplantation and early mortality [1–5].

The risk of hepatic artery thrombosis would seem to be higher in living donor liver transplantation because the right or left hepatic arteries of the donor graft are shorter and smaller in diameter than the more proximal arteries available with cadaveric grafts. This has indeed been the case in centers that perform both kinds of liver transplants [6,7].

The risk of hepatic artery thrombosis is also higher in pediatric liver transplantation [4,8–16]. The obvious reason is the small size of the recipient artery. Another factor may be the greater utilization of the left lobe or left-lateral segment of the donor, which is more likely, anatomically, to have more than 1 artery with a short length and small diameter. This is most common in infants, although the technical problem is offset somewhat by the hypertrophy of the hepatic artery seen in many pediatric patients with cirrhosis due to biliary atresia (in whom the problem of low portal flow from the hypoplastic portal vein tends to predominate). In smaller infants, the difficulty in closing the abdominal wall over a large-sized graft can also contribute to an increased incidence of hepatic arterial complications.

Many methods have been used to prevent hepatic artery complications, which include routine anticoagulation [17–21], the use of greater magnification to reconstruct the hepatic artery [19,21–25], having a microvascular surgeon do the hepatic artery reconstruction [26,27], and other methods [28]. However, it is not clear that the improvement in the hepatic artery thrombosis rate is due to the change in technique rather than increasing surgical experience [29]. Transplant centers that have reverted back from greater to lesser magnification have also seen a decrease in complication rates [30], as have centers that have changed from having microvascular surgeons performing the reconstruction to transplant surgeons performing them [31]. It seems evident that high-volume transplant centers tend to develop a standardized technique for doing hepatic artery reconstruction with relatively low complication rates [32].

Liver transplantation in India has been predominantly the living donor type because of the low deceased organ donation rates [33]. The huge population of the country is served by a small number of transplant centers, which have high volumes. The lack of an alternative to deceased organ donation has forced these centers to accept all patients for living donor liver transplant, including patients with fulminant hepatic failure and severely decompensated cirrhotics with maximal Model for End-Stage Liver Disease scores. This has also resulted in pressure to reduce the incidence of hepatic artery complications, since a salvage retransplant is usually not possible.

In the early part of the transplant experience in the present series, the hepatic artery reconstruction was performed by a single surgeon and the relatively low incidence of complications may be attributable to his surgical skill and personal learning curve-plateau [34]. The microvascular surgeons were asked to perform the more technically demanding hepatic artery reconstructions. However, after the lead surgeon at our center moved to another transplant center, a more standardized and reproducible technique was developed, which could be used by multiple surgeons with equal or superior results and without the need for microsurgical techniques.

In this study, we aimed to demonstrate that the "W" technique provides results that are at least equal, if not superior, to the standard technique for reconstruction of the hepatic artery.

Material and Methods

This series included all patients undergoing liver transplants at 2 centers (Sir Ganga Ram Hospital, New Delhi from March 2007 to November 2012 and Kokilaben Dhirubhai Ambani Hospital, Mumbai from March 2013 to April 2016). The gap is owing to the time taken to establish a new liver transplant program at the Mumbai center. Patient data were collected in a database prospectively and updated during outpatient visits as required.

Most of the liver transplants were living donor liver transplants. The few deceased donor liver transplants performed during this period have also been included since the "W" technique was applicable to them as well. This series also included some pediatric living donor liver transplants because the same technique was used in them.

Protocol Doppler studies were performed by a dedicated radiologist intraoperatively and postoperatively for 5 consecutive days. Doppler studies were also performed in patients with unexpected derangements of the serum transaminases. If the waveform was unsatisfactory in the intraoperative Doppler, the arterial anastomosis was revised and the Doppler study was repeated.

If the postoperative Doppler study showed absence of flow or low flow, then a computed tomography (CT) arteriogram was performed. If this confirmed hepatic artery thrombosis, then the decision was made to either attempt angiography and thrombolysis or to perform surgical revision. Surgical revision was preferred when hepatic artery thrombosis occurred

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within 5 days of transplantation. Protocol Doppler studies were also performed at 3 months after transplantation, 1 year after transplantation, and annually thereafter.

From March 2007 to June 2010, nearly all the hepatic artery anastomoses were performed by a single surgeon. After that, the "W" technique was introduced and the arterial anastomoses were performed by 5 different surgeons in rotation, using 2.5× to 3.5× surgical loupes. Plastic surgeons were requested to perform the arterial reconstruction under the operating microscope when the diameter of the artery, intimal dissection of the artery on the donor side, or disparity in luminal diameter made the reconstruction technically difficult. The conventional method of arterial reconstruction was an end-to-end anastomosis with 7.0 polypropylene (Prolene, Ethicon) interrupted sutures.

The "W" technique has been described in detail elsewhere [35] but a brief description is provided here. During the recipient hepatectomy, care was taken to preserve as much length of the hepatic arteries as possible. To avoid damage, the arteries were not directly held with any instrument or vascular slings. The use of ligaclips was preferred to ties to avoid crumpling of the intima.

In the donor, the artery was dissected up to the last branch to the remnant, which was often the segment 4 artery, but was sometimes the bifurcation of the proper hepatic artery into the left and right hepatic artery. Care was taken to not completely bare the artery, leaving some tissue around it to prevent kinking and to facilitate handling. When removing the graft, the donor was given 50 units/kg of heparin at least 3 min before placing a clamp on the artery. The graft side of the artery was cut sharply with a fine scissor without any clamps. The donor stump was suture ligated with 5.0 polypropylene (Prolene, Ethicon) sutures.

During implantation, the arterial reconstruction was performed after reperfusing the graft with portal blood. A light plastic bulldog clamp was applied on the graft hepatic artery to prevent back-bleed and the artery was flushed with heparinized saline (50 units/mL). A heavier metallic bulldog clamp was applied on the recipient artery, taking care to orient the anterior-posterior lie of the artery. The artery was sharply cut proximal to the ligaclip with a micro-scissor. The clamp was briefly released to confirm good flow and was then reapplied. The artery was then flushed with heparinized saline.

The anterior (12 o'clock) suture was first placed using a 7.0 polypropylene (Prolene, Ethicon) suture with 2 stitches passing each needle from inside out. Next, the posterior (6 o'clock) suture was placed in a similar fashion. The ends of the sutures were held with rubber-shod "mosquito" forceps.

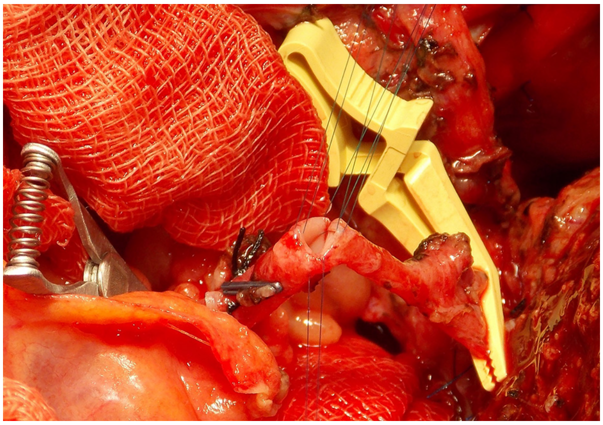

Figure 1. Operative photograph showing the hepatic artery splayed out by the "W" technique.

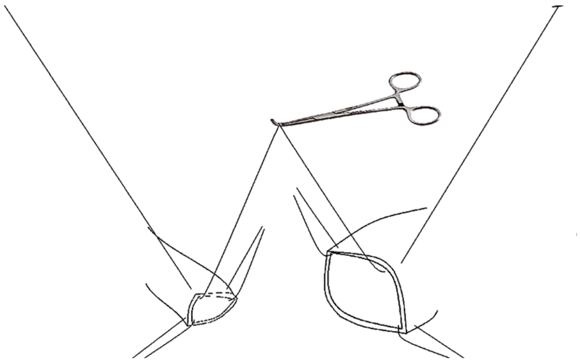

Figure 2. Schematic representation of the "W" technique.

The anterior suture was pulled over to the left side of the patient and the posterior suture to the right side of the patient, exposing the right sides of both arteries. This was a 90-degree rotation to the right.

The middle stitch was placed first, again passing the needles from inside out. Holding the ends of this suture, the loop of suture was hooked up (**Figure 1**). In this configuration, the suture is shaped like a "W", hence the name of the technique (**Figure 2**). The 2 ends and the loop are held in a rubber-shod clamp.

The "W" stitch splays out the orifice of the artery, permitting accurate placement of the next 2 sutures, again from inside out on either side of the "W" stitch, halfway between it and the corners (**Figures 3, 4**). The loop of the "W" was released and the ends pulled up, letting the central stitch also fall into place. Next, the stitches were tied (**Figure 5**).

The arteries were then turned over to expose the left side (**Figure 6**). Again, this involves only a 90-degree rotation. The same technique was used on the left side (**Figure 7**). A total of 8 evenly spaced interrupted sutures were thus placed and tied.

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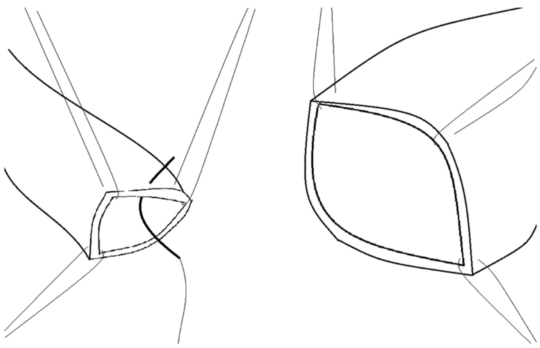

Figure 3. Schematic representation demonstrating placement of the suture from the inside out between the "W" suture and the corner suture.

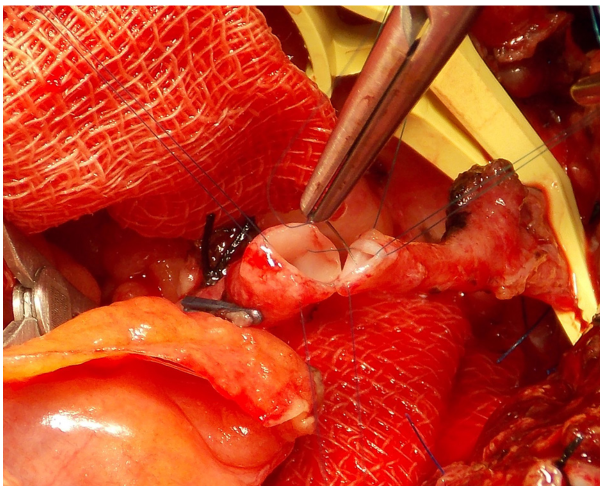

Figure 4. Operative photograph showing the placement of the suture between the "W" suture and the corner suture from the inside out. The ostium of the artery is splayed out into a triangle making accurate placement of the sutures easy, even in the presence of luminal disparity.

The light plastic bulldog clamp on the graft side was released first. Usually backflow filled the artery in a retrograde fashion. Sometimes, the artery remained flattened at the site of application of the bulldog clamp. Gently rolling the artery between the fingers opened it up. Lastly, the bulldog clamp on the recipient artery was released. Pulsatile bleeding from the edge of the bile duct often provided independent corroboration of good arterial flow at this point.

A Doppler study was then performed by a radiologist who had experience in liver transplant cases. Apart from confirming adequate flow in the portal vein, hepatic veins, and the hepatic artery, particular attention was paid to the hepatic artery waveform in a branch well within the liver. A sharp upstroke indicated good inflow. The peak velocity and the resistive index were recorded. In case of a suboptimal hepatic artery waveform, the anastomosis was dismantled and reconstructed. The bile duct reconstruction was performed after the hepatic artery Doppler study.

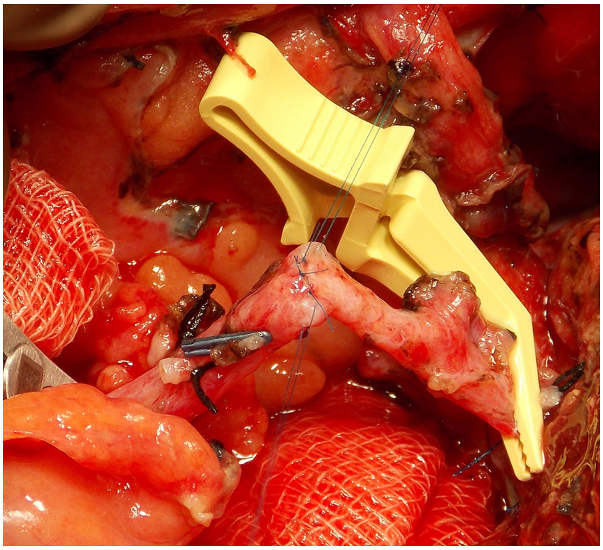

Figure 5. The 3 sutures on the right side of the anastomosis are tied.

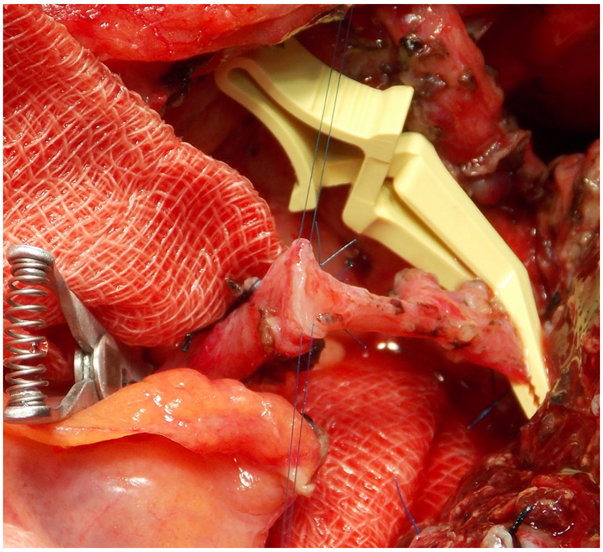

Figure 6. The arteries are turned back up to the neutral position and then 90 degrees to the other side exposing the left side (note that this technique does not at any stage require more than a 90-degree rotation from the neutral position).

The outcomes of the patients who had the standard hepatic artery reconstruction were compared to the outcomes of patients who had the hepatic artery reconstructed using the "W" technique. Categorical variables were compared using the Fisher's exact test for difference of proportions.

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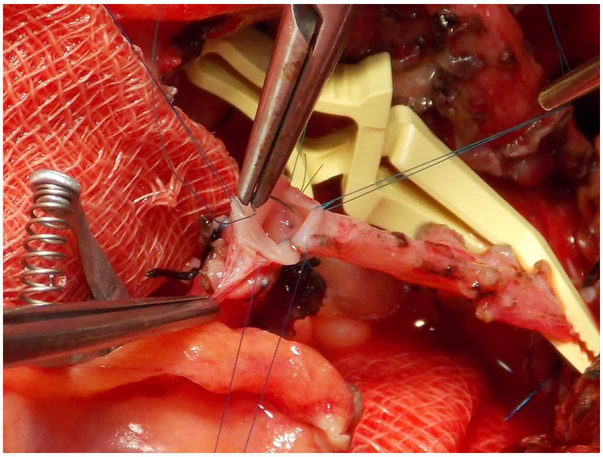

Figure 7. Similarly, the anastomosis is completed by placing a "W" stitch in the middle on the left side and using it to splay out the ostium and place sutures from inside-out on either side midway between the "W" suture and the corner sutures.

Table 1. Etiology of liver disease.

Hepatitis B or C	29.5%
Alcoholic liver disease	20.0%
Non-alcoholic fatty liver disease	20.0%
Autoimmune hepatitis	3.3%
Acute liver failure	5.9%
Acute-on-chronic liver failure	2.6%
Cryptogenic and others	34.2%

Results

From March 2007 to April 2016, 675 liver transplants were performed. Of these, 27 (4%) were deceased donor liver transplants and 648 (96%) were living donor liver transplants. There were 63 pediatric transplants (9.3%), all of which were living donor transplants. Of the living donor liver transplants, 589 used right lobes (85.5%), 48 used left lobes (7%), 20 used left-lateral segments (2.9%), 3 were dual lobe transplants (right lobe and left lobe from different living donors), and 1 was a domino liver (the domino donor who had maple syrup urine disease (MSUD) received a living donor left-lateral segment and the whole liver of the MSUD patient was given to the domino recipient). The remaining 3.9% were deceased donor livers, one of which was split, with the left lobe used in a small adult recipient in our institution and the right lobe used at another institution.

Eighty percent of the recipients (549) were male patients. Emergency transplants for fulminant hepatic failure accounted for 5.7% (39) of transplants, while patients with acute-on-chronic liver failure accounted for 2.6% (18). Hepatocellular carcinoma was the main or additional indication for transplantation in 87 patients (12.8%). Among patients undergoing liver transplantation for decompensated cirrhosis, hepatitis B or C were the most common indications (29.5%), followed by alcoholic liver disease (20%), cryptogenic cirrhosis (16.1%), non-alcoholic fatty liver disease (4.5%), autoimmune hepatitis (3.3%), and other less common indications (**Table 1**).

The first 442 patients undergoing transplantation in the series had hepatic artery reconstruction done using a standard interrupted anastomosis technique under surgical loupes, with magnification of 2.5× to 3.5×. When the anastomosis was technically complex, the plastic surgery team was requested to perform the reconstruction under the operating microscope. This was required in 12 instances (2.7%). After July 2010, the "W" technique became the preferred method of reconstruction. It was not technically possible in 1 case in which dissection of the graft hepatic artery required trimming it right up to its entry into the hepatic hilar plate, in which it was not possible to rotate the graft artery at all. After changing to the "W" technique, plastic surgeons were required in only 2 arterial reconstructions (0.9%), both in the early part of our experience with the technique. The assistance of the operating microscope was not required in the last 191 liver transplants.

There were 9 hepatic artery thromboses in the 443 standard hepatic artery reconstructions (2.0%). One of these was in a patient who had a reconstruction under the microscope. With the "W" technique, there were 2 hepatic artery thromboses in 232 transplants (0.86%). The difference between the 2 groups was not significant (Fisher's exact test statistic, P=0.34).

There was 1 hepatic artery thrombosis in 63 pediatric liver transplants (1.5%). This child was in the standard reconstruction group.

The details of the outcomes of patients with hepatic artery thrombosis are shown in **Figure 8 and Table 2**. Among the 9 patients with hepatic artery thrombosis in the standard reconstruction group, 8 had early hepatic artery thrombosis within 1 week after transplantation. One pediatric patient had thrombosis of the hepatic artery and portal vein. On surgical exploration, the patient's liver was found to be necrotic. The portal vein was arterialized, but the patient died soon after. One adult patient had no backflow from the donor hepatic artery and, despite attempts at thrombolysis with urokinase, arterial flow could not be restored. A living donor retransplant was done. The patient recovered and is alive and well. Six patients underwent successful surgical revascularization of the hepatic artery. One of them had rethrombosis within 48 h. This patient underwent a living donor retransplant and is alive and well. Five patients maintained patent arteries with functioning grafts. Two

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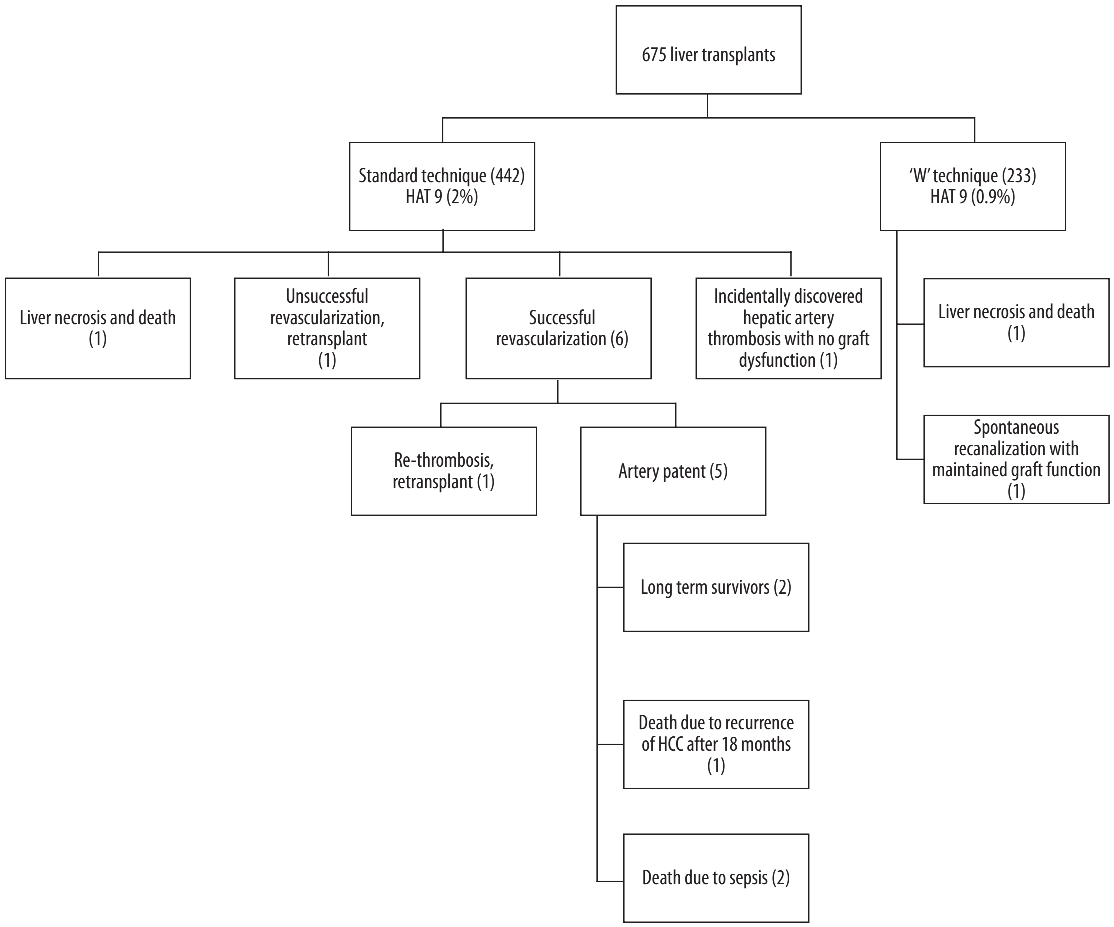

Figure 8. Flowchart of outcomes of hepatic artery thrombosis.

Table 2. Outcome of hepatic artery thrombosis.

	Standard technique (442)	"W" technique (233)	*P* value
Hepatic artery thrombosis	9 (2.0%)	2 (0.9%)	0.34
Graft loss	3 (0.67%)	1 (0.42%)	0.28
Need for microscope	12 (2.7%)	2 (0.8%)	0.06

died of sepsis with functioning grafts. Of the 3 patients who recovered and were discharged home, 2 are alive and well and 1 had a recurrence of hepatocellular carcinoma in the lungs and bone 1 year after transplant and died 18 months after transplantation. The patient's tumor was within the Milan criteria at the time of transplant. One patient, whose hepatic artery thrombosis was discovered incidentally, maintained normal liver functions 2 weeks after the transplant, did not develop biliary complications, and remains well without any intervention.

Overall, the graft survival in this group of 9 patients was 4/9 (44%) and the patient survival was 6/9 (55%). However, note that 1 of the 6 survivors eventually died from a hepatocellular carcinoma recurrence at 18 months after the transplant.

In the cohort of 232 arterial reconstructions using the "W" technique, there were 2 hepatic artery thromboses. One patient with overwhelming sepsis soon after the transplant required high doses of pressors to maintain blood pressure. He developed thrombosis of the hepatic artery and the portal vein. Upon surgical exploration, the liver was found to be necrotic, and the patient died soon after surgery. It is likely that, in this case, sepsis and the low-flow state resulting from high doses of pressors may have caused vascular thrombosis.

The second patient had an asymptomatic hepatic artery thrombosis diagnosed when a CT scan was done to evaluate the cause of an elevated white blood cell count. An angiography was performed but flow could not be reestablished. Since the liver function was normal, surgical exploration was

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not performed, to avoid disrupting any collateral circulation that might have developed. Low-molecular-weight heparin was started. The patient's liver function tests remained normal and a CT scan performed 3 months after the transplant showed recanalization of the hepatic artery.

In this cohort of patients, the rate of graft loss due to hepatic artery thrombosis was 1/232 (0.4%).

There were no late hepatic artery thromboses (beyond 30 days from the date of transplant).

There have been no graft losses due to hepatic artery thrombosis in the last 232 liver transplants (199 living donor transplants and 33 deceased donor transplants) in this series, in addition to transplants performed after the time period of the study.

Discussion

Reconstruction of the hepatic artery is often the technically most demanding part of a liver transplant because the diameter of the artery is small and there is often a mismatch between the diameter of the donor artery and that of the recipient. In deceased donor transplantation, careful benching and the availability of long lengths of hepatic artery and a patch of the aorta allow surgeons to optimize the artery available for reconstruction during implantation of the liver. Artery length is not a constraint and when arterial complications are encountered, complications probably reflect atherosclerotic changes in the arteries of the patient or the donor. In elderly donors, surgeons often palpate the hepatic artery, and a 'crunchy' artery beyond the gastroduodenal branch may be a valid reason to decline the use of the liver for transplantation. The present series is from a predominantly living donor liver transplant program, in which only 27 of 675 liver transplants were from deceased donors. There were no arterial complications in the deceased donor transplants. Due to familiarity with the technique, the arterial reconstructions in these transplantations were performed using the same technique as in the living donor transplantations.

The risk of arterial complications is certainly higher in living donor transplantation than in deceased donor transplantation. When the right lobe of the liver is used, as is the case in most adult-to-adult transplants, there may be more than a single artery to the graft. For instance, there may be an accessory right hepatic artery from the superior mesenteric artery, or the right hepatic artery may divide into anterior and posterior sectoral branches to the left of the common hepatic duct with one branch passing behind the duct and one in front. Another anomaly is a segment 4 artery arising from the anterior sector artery, making it imperative to divide this artery beyond the segment 4 branch. When the left lobe is used for transplantation, the artery to the left-lateral segment and the segment 4 artery may be separate, small in diameter, and short in length and require reconstruction separately.

In the first large series of living donor liver transplants, the incidence of hepatic artery thrombosis was 20 in the first 84 patients (23.8%) [19]. As the surgical technique was refined and made less complex, the incidence of arterial complications decreased, and the authors reported no hepatic artery thromboses in their next 20 transplants. They attributed the improvement to not using interposition grafts, using a microvascular technique, and instituting an anticoagulation protocol.

The A2ALL study group reported a higher incidence of hepatic artery thromboses in patients undergoing living donor transplants than in patients undergoing deceased donor transplants (6.5% *vs.* 2.3%) [6]. They also reported a "learning curve effect" with centers having experience of more than 20 living donor liver transplants reporting a lower incidence of complications than those with less experience. In the present series of transplants, the transplant volume was well beyond that at which the rate of technical complications would have plateaued. The only change was the adoption of the "W" technique from July 2010 onward.

The higher risk of hepatic artery thrombosis in pediatric liver transplants was not observed in this series. However, pediatric transplants accounted for less than 10% of the transplants. The single occurrence of hepatic artery thrombosis was seen early in our experience when an infant who underwent a reduced left-lateral segment transplant became dehydrated after a dose of furosemide and thrombosed the hepatic artery and portal vein. Children with cholestatic liver diseases such as biliary atresia develop a low portal flow and hypertrophy of the hepatic artery, resulting in a relatively easy arterial reconstruction. Since we had only a single hepatic artery thrombosis in the pediatric transplants in the standard technique group and none with the "W" technique group, a useful statistical comparison could not be performed. However, the paucity of complications does emphasize that the "W" technique can be used safely in pediatric living donor liver transplants.

Some transplant centers advocate routine anticoagulation in all patients undergoing liver transplants to reduce the risk of hepatic artery thrombosis [17]. Some advocate selective anticoagulation for smaller children [19]. It has been suggested that a hypercoagulable state may exist for some time after a liver transplant owing to acceleration of the coagulation system and delayed recovery of the fibrinolytic system [18]. However, centers with much experience in pediatric liver transplantation [23] have moved away from the routine use of anticoagulation as their technique has become more standardized.

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Another strategy has been to use greater magnification by performing the arterial reconstruction under an operating microscope. However, this strategy is not without problems. The microvascular surgeon is still limited by the quality of the artery that has been provided. The field of work is deep in the abdomen, unlike the surface stable fields most microvascular surgeons are accustomed to, and the movement with respiration must be accounted for. The University of Chicago group reported a decrease in the incidence of hepatic artery thrombosis from 22% to 0% after switching to microvascular techniques [19]. However, they also made other changes to their technique, including the use of anticoagulation in children under than 20 kg and avoidance of saphenous vein grafts, which they were using routinely in the earlier part of their experience. Similarly, the Kyoto University team reported 1 hepatic artery thrombosis in their first 8 living donor transplants, in which the arterial reconstructions were performed using surgical loupes, and 4 thromboses in the next 242 transplants, in which the arterial reconstruction was performed under a microscope [22]. A compromise between the operating microscope and conventional fixed magnification loupes was offered by a head mounted varioscope with higher magnification and a zoom option. Ohdan et al. reported 89 living donor liver transplants using the varioscope, with no arterial complications [36]. Interestingly, some transplant centers have moved in the opposite direction. Marubayashi et al. reported that they performed hepatic arterial reconstruction using the operating microscope for their first 84 living donor liver transplants and then began doing them using surgical loupes [30]. They also had better outcomes of reduced operative time with the loupes. Other centers have also reported excellent outcomes using surgical loupes. Li et al. reported a 1.66% incidence of hepatic artery thrombosis in 188 adult-to-adult living donor liver transplants [37]. The arterial anastomoses were performed by cardiovascular surgeons using surgical loupes with 4.5× magnification. The overall impression is that the incidence of hepatic arterial complications seems to reduce as surgeons gain experience in performing the procedure. This seems to happen whether they move from lower to higher magnification or vice versa. In our standard technique group, 1 of 12 reconstructions performed under the microscope developed hepatic artery thrombosis (8.3%). However, it should be noted that these were selected cases in which microsurgical reconstruction was chosen because of technical difficulties and are not comparable with the cases in which the microscope was not required.

Other centers have also reported a high incidence of hepatic artery thrombosis in the early part of their experience. As experience increases, the incidence of hepatic arterial complication decreases. Yang et al. reported 182 adult-to-adult living donor liver transplants in which the hepatic artery reconstruction was performed under surgical loupes (3.5×) by a group of vascular surgeons [26]. In the first 58 patients in their series, hepatic artery thrombosis was encountered in 4 patients. There were no arterial complications in the next 124 cases.

The existence of the learning curve has led to different strategies. Some centers turned to plastic and microvascular surgeons to perform all hepatic artery reconstructions [19,23], whereas others have reported good outcomes when cardiovascular surgeons have performed the reconstructions [26,37]. However, these strategies are associated with potential drawbacks. Transplant surgeons performing the recipient hepatectomy may be less careful in the dissection of the arteries when they know they will not be responsible for the arterial reconstruction. In fact, Yan et al. reported that arterial anastomosis performed by the transplant surgeon reduced the risk of arterial complications [31]. It is also suboptimal for the liver transplantation to require more complex scheduling to account for the availability of the operating microscope and the microvascular surgeon. The most important drawback is that the transplant surgeons trained at such an institution would never learn to perform an arterial reconstruction.

In the early part of the present series, keeping the learning curve effect in mind, all the arterial reconstructions were performed by a single surgeon. This was an effective strategy since it resulted in the very low incidence of arterial complications of 2%. In 2010, the senior surgeon performing all the arterial reconstructions moved to a different institution and the remaining surgeons with relatively less experience in performing arterial reconstructions (as a result of the previous strategy of having a single surgeon performing all the arterial anastomoses) felt the need to standardize the technique so that it could be performed safely by all the surgeons. The "W" technique was the result of this effort and became a way for all the surgeons to perform the arterial reconstruction in the same way without much dependence on technical virtuosity. This led to the reduction in the requirement for involving the microvascular surgeons (2.7% to 0.86%) and in the incidence of hepatic artery thrombosis (2% to 0.86%). The number of hepatic artery thromboses was too small to show a significant difference on statistical analysis, but the "W" technique has certainly proven to be safe and easy to learn and has a much shorter learning curve than other methods. We are not claiming that the method is novel, and it is certainly possible that other transplant centers are using this technique, but we have not found a detailed description of the method and its outcomes in the literature. We are also not claiming that this method is better than the conventional technique used earlier. The number of arterial complications was very small with either technique (and hence did not reach statistical significance) but the conventional technique was operator dependent and less reproducible. We believe the "W" technique is less operator dependent, easier to teach and learn, and more standardized, with

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less scope for error. Although this technique is most useful in living donor liver transplantation, we performed the arterial reconstruction in the same manner in the small number of deceased donor liver transplants in this series because of our familiarity with the technique. There were no hepatic artery thromboses in the deceased donor transplants.

Our results illustrate that, since the microscope was not required in our last 191 liver transplants and there were no graft losses in the last 232 liver transplants, the "W" technique is easy to perform and safe.

Conclusions

The "W" technique is a standardized technique for reconstruction of the hepatic artery in living donor liver transplantation, with a low incidence of hepatic arterial complications (0.86%). It can be easily taught and has a short learning curve.

Institutions where the work was performed

Sir Ganga Ram Hospital, New Delhi, India and Kokilaben Dhirubhai Ambani Hospital, Mumbai, India.

Conflict of interest

None.

References:

1. Settmacher U, Stange B, Haase R et al: Arterial complications after liver transplantation. Transplant Int, 2000; 13: 372–78
2. Pfitzman R, Bensheitd B, Langehr JM et al: Trends and experiences in liver retransplantation. Liver Transplantation, 2007; 13: 248–57
3. Yang Y, Zhao JC, Yan LN et al: Risk factors associated with early and late HAT after adult liver transplantation. World J Gastroenterol, 2014; 20: 10545–52
4. Bekker J, Ploem S, de Jong KP et al: Early hepatic artery thrombosis after liver transplantation: a systematic review of the literature. Am J Transplant, 2009; 9: 746–57
5. Astarcıoglu I, Egeli T, Gulcu A et al: Vascular complications after liver transplantation. Exp Clin Transplant, 2019 [Online ahead of print]
6. Friese CE, Gillespie BW, Koffron AJ et al: Recipient morbidity after living and deceased donor liver transplantation: findings from the A2ALL retrospective cohort study. Am J Transplant, 2008; 8: 2569–79
7. Khalaf H: Vascular complications after deceased donor and living donor transplantation: A single-center experience. Transplant Proc, 2010; 42: 865–70
8. Vasavada B, Chen CL: Vascular complications in biliary atresia patients undergoing living donor liver transplantation: Analysis of 110 patients over 10 years. J Indian Assoc Pediatr Surg, 2015; 20: 121–26
9. Moray G, Yezcaver T, Akdur A et al: Results of pediatric liver transplant: A single-center experience. Exp Clin Transplant, 2015; 13: 59–63
10. Uehida Y, Sakamoto S, Egawa H et al: The impact of meticulous management for hepatic artery thrombosis on long-term outcome after pediatric living donor liver transplants. Clin Transplant, 2009; 23: 392–99
11. Neto JS, Carone E, Pugliese V et al: Living donor liver transplantation for children in Brazil weighing less than 10 kg. Liver Transpl, 2007; 13: 1153–58
12. Haberal M, Karakayali H, Arslan G et al: Liver transplantation in children weighing less than 10 kilograms. Transplant Proc, 2006; 38: 3585–87
13. Shirouzu Y, Kasahar M, Morioka D et al: Vascular reconstruction and complications in living donor liver transplantation in infants weighing less than 6 kg: The Kyoto experience. Liver Transpl, 2006; 12: 1224–32
14. Heffron TG, Welch D, Pillen T et al: Low incidence of hepatic artery thrombosis after pediatric liver transplantation without the use of intraoperative microscope or parenteral anticoagulation. Pediatr Transplant, 2005; 9: 486–90
15. Goss JA, Shakleton CR, McDiarmid SC et al: Long-term results of pediatric liver transplantation: An analysis of 569 transplants. Ann Surg, 1998; 228: 411–20
16. Stevens LH, Emond JC, Piper JB et al: Hepatic artery thrombosis in infants. A comparison of whole livers, reduced-size grafts and grafts from living-related donors. Transplantation, 1992; 53: 396–99
17. Sugawara Y, Kaneko J, Akamatsu N et al: Anti-coagulant therapy against hepatic artery thrombosis in living donor liver transplantation. Transplant Proc, 2002; 34: 3325–26
18. Hashikura Y, Kawasaki S, Okamura N et al: Prevention of hepatic artery thrombosis in pediatric liver transplantation. Transplantation, 1995; 60: 1109–12
19. Mills JM, Cronin DC, Brady LM et al: Primary living-donor liver transplantation at the University of Chicago. Technical aspects of the first 104 recipients. Ann Surg, 2000; 232: 104–11
20. Malago M, Testa G, Freilling A et al: Living donor liver transplantation: An option for adult patients. Single institution experience with 74 patients. Ann Surg, 2003; 238: 853–63
21. Miyagi S, Enomoto Y, Sekiguchi S et al: The effects of gebexate mesylate on the microsurgical reconstruction of the hepatic artery in living donor liver transplantation. Transplant Proc, 2010; 42: 4158–60
22. Hatano E, Terajima H, Yabe S et al: Hepatic artery thrombosis in living related liver transplantation. Transplantation, 1997; 64: 1443–46
23. Neto JS, Pugliese R, Fonseca EA et al: Four hundred thirty consecutive pediatric living donor liver transplants: Variables associated with post transplant patient and graft survival. Liver Transpl, 2012; 18: 577–84
24. Okazaki M, Asato H, Takushima A et al: Hepatic artery reconstruction with double-needle microsuture in living-donor liver transplantation. Liver Transpl, 2006; 12: 46–50
25. Amin AA, Kamel R, Hatata Y et al: Crucial issues of hepatic artery reconstruction in living donor liver transplantation: Our experience with 133 cases at Dar-El-Fouad Hospital, Egypt. J Reconstruct Microsurg, 2009; 25: 307–12
26. Yang Y, Yan LN, Zhao JC et al: Microsurgical reconstruction of hepatic artery in A-A LDLT: 124 consecutive cases without HAT. World J Gastroenterol, 2010; 16: 2682–88
27. Hernanadez JA, Mullens CL, Aoyama JT et al: Analysis of outcomes in living donor liver transplants involving reconstructive microsurgeons. J Recontruct Microsurg, 2020; 36: 223–27
28. Miyagi S, Enomoto Y, Sekiguchi S et al: Microsurgical back wall support suture technique with double needle sutures on hepatic artery reconstruction in living donor liver transplantation. Transplant Proc, 2008; 40: 2521–22
29. Salvalaggio PR, Modanlou KA, Edwards EB et al: Hepatic artery thrombosis after adult living donor liver transplantation: The effect of center volume. Transplantation, 2007; 84: 926–28
30. Marubayashi S, Kobayashi S, Wada H et al: Hepatic artery reconstruction in living donor liver transplantation: risk factor analysis of complications and a role of MDCT scan for detecting anastomotic stricture. World J Surg, 2013; 37: 2671–77
31. Yan S, Zhang QY, Yu YS et al: Microsurgical reconstruction of hepatic artery in living donor liver transplantation: Experiences and lessons. Hepatobiliary Pancreat Dis Int, 2009; 8: 575–80
32. Park G-C, Moon D-B, Kang S-H et al: Overcoming hepatic artery thrombosis after living donor liver transplantations: An experience from Asan Medical Center. Ann Transplant, 2019; 24: 588–93
33. Hibi T, Wei CAK, Chan A, Bhangui P: Current status of liver transplantation in Asia. Int J Surg, 2020; 82S: 4–8

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34. Soin AS: Smoothing the path: Reducing biliary complications, addressing small-for-size syndrome, and making other adaptations to decrease the risk for living donor liver transplant recipients. Liver Transpl, 2012; 18 (Suppl. 2): S20–24
35. Nath B, Mehta N, Kumaran V: Living donor liver transplant: Implantation of the graft. Techniques of liver surgery. 1st edition. New Delhi: Jaypee Brothers Medical Publishers (P) Ltd., 2016; 125–38
36. Ohdan H, Tashiro H, Ishigama K et al: Microsurgical hepatic artery reconstruction during living donor liver transplantation by using head-mounted surgical binocular system. Transplant Int, 2007; 20: 970–73
37. Li PC, Jeng LB, Yang HR et al: Hepatic artery reconstruction in living donor liver transplantation: Running suture under surgical loupes by cardiovascular surgeons in 180 recipients. Transplant Proc, 2012; 44: 448–50
38. Jeon JS, Won JH, Wang HJ et al: Endovascular treatment of acute arterial complications after living donor liver transplant. Clin Radiol, 2008; 63: 1099–105
39. Jurin O, Shackleton CR, McDiarmid SV et al: Living donor liver transplantation at UCLA. Am J Surg, 1995; 169: 529–32

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