Flow-Assisted Surgical Technique F•A•S•T during Transplant Surgery

Contents

Transplant Surgery

"The routine use of intraoperative flow measurements of the hepatic artery may be a useful adjunct in identifying the hepatic artery reconstruction, which is at risk of subsequent hepatic arterial thrombosis (HAT)."
M. Lin, MD

Transit Time Ultrasound Volumetric Measurements

Liver transplantation is the standard of care and the only cure for end stage liver disease. Its success has led to over 4,500 transplants performed yearly. Orthotopic liver transplantation presents a unique opportunity for intraoperative flow measurements because the liver is supplied by two vessels, the portal vein and the smaller oxygenated hepatic artery. Both have to be patent for a transplanted liver to survive and the hepatic artery is known to thrombose (HAT). Transonic's flowprobes can measure these two flows simultaneously during transplantation surgery and provide a quality measure before closing the patient.

Liver Transplant Surgeon Presents at FASEB

At a Federation of American Societies for Experimental Biology (FASEB) convention in Atlanta in the early 1990s, one of the presenters at a Transonic-sponsored forum was Dr. Michael Henderson, transplantation surgeon at Emory University Medical School. He presented his use of intraoperative flow measurements to measure hepatic arterial and portal venous flows during orthotopic liver transplantation in human subjects. After the subsequent publication of his study in the British Journal of Hepatology in 1993, interest in Transonic's capability to simultaneously measure hepatic arterial and portal venous flows quickly took hold and major liver transplantation centers such as Barnes Jewish Hospital in St. Louis and Northwestern University Hospital in Chicago purchased a dual-channel flowmeter to measure flow during their transplant surgeries.

Adult to Adult Living Donor Liver Transplantation (AALDLT)

Because the need for livers for persons with liver disease far out paces their availability from cavaderic donors, adult-to-adult living donor liver transplantation (AALDLT) has become accepted and is being performed. The procedure is challenging and the risks are potentially greater because the live donor contributes a large portion of his or her liver to the recipient. "It takes a lot of love to give someone a part of your liver," commented Dr. J. Emond, chief of Columbia Presbyterian's Transplantation Center.
To accumulate sufficient data about the procedure, the National Institutes of Health is sponsoring a multi-center study to aid decisions made by physicians, patients, and potential donors about this risky operation. Transonic is collaborating with the centers participating in the study by supplying the tools needed to obtain reliable flow information.

Renal Transplantation

Although the imperative to measure renal arterial flow during renal transplantation is not as urgent as measuring flow during liver transplantation because a kidney will turn pink to red immediately upon perfusion after being transplanted, numerous centers also measure renal arterial blood flow during transplantation. Transplant surgeons at Hermann Hospital in Houston have used both the laser Doppler flowmeter as well as the transit-time ultrasound flowmeter to measure both donor and recipient perfusion and flow respectively, during live donor kidney transplantation. The development of laparoscopic flowprobes for use during laparoscopic organ removal promises to expand this application opportunity.

Kidney/Pancreas Transplantation

Transplantation of a pancreas is often paired with a simultaneous kidney transplant in insulin-dependent diabetes patients who have developed end-stage renal failure. These complicated procedures ofter an opportunity to measure both the portal venous outflow from the transplanted pancreas and the iliac arterial flows.

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Flow Protocol: Liver Transplantation

Intraoperative Blood Flow Measurement during Adult Orthotopic Liver Transplantation

Courtesy of J. Michael Henderson, MD, FACS

Introduction

Abnormal hepatic hemodynamics and physiology in the transplanted liver pose continuing challenges for the surgeon. A practical method for measuring two of these hemodynamic parameters, portal venous and hepatic arterial flows, is by intraoperative flow measurements. Transit-time ultrasound technology is well suited to measure these flows. Flowprobes are easily applied and do not have to be applied tightly to vessels; they simply encompass the vessel.

Surgical Approach

Measurement of portal venous and hepatic arterial flows can be easily done at the completion of orthotopic liver transplantation using Transonic Flowprobes. Following completion of the vascular anastomoses, the new liver is reperfused, and hemostasis achieved. Prior to biliary reconstruction, the Flowprobes are placed on the reconstructed portal vein and hepatic artery.

The Probes are chosen to comfortably encompass - but not constrict - the vessels, and are placed such that extraneous tissue is excluded. The field is then immersed in saline which serves as a good acoustic contact with the vessels. Readings stabilize rapidly, usually within 1-2 minutes, and in stable patients fluctuate less than ± 10% when left in situ for 10-15 minutes. If there is wider fluctuation, this usually indicates improper positioning of the Flowprobes with poor alignment or extraneous tissue, and can normally be corrected by repositioning. Arterial flow readings are meaningful over a brief snapshot period. Venous flow exhibits a far slower rhythm, dictated by events such as gastric motility. A one-to-five minute observation period is often adequate.

Discussion

Combined portal venous and hepatic artery flow are usually 15 - 25% of cardiac output. Of clinical importance is hepatic artery patency and flow, as survival of the graft depends on this. Flowprobes provide a volumetric measure of hepatic artery flow, and when this is low can be used to determine if there is a fixed anatomic limitation to flow or a physiologic limitation. For example, in a patient with a cardiac output of 10 L/min, portal flow of 2000 ml/min and hepatic artery flow of 75 ml/min, reduction of portal flow to 1000 ml/min resulted in a hepatic artery flow increase to 125 ml/min. Thus, the low basal hepatic artery flow resulted from a high physiologic resistance rather than a fixed, potentially surgically correctable low inflow. This kind of data can be captured on the flowmeter's strip chart recorder or AureFlo's snapshot/recording for a permanent record.

The information obtained with these transit-time ultrasound Flowprobes is often at variance with "clinical impression." A transplant with obstructed hepatic artery may show a strong pressure pulse on the artery, and a healthy organ color due to its venous perfusion. Accurate information on volumetric flow at the time of operation can either be reassuring, or may indicate an unexpected problem which can be fixed at this time. In a procedure such as liver transplant, where the stakes are high, this technology can be a useful adjunct in operative decision.

(Continued on next page)

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Flow Protocol: Liver Transplantation cont.

Subsequent studies have identified the following intraoperative flow indices related to poor outcomes:

- Poor outcome is associated with graft hyperfusion. Recipient portal venous flow in the recipient should be lowered when graft to recipient body weight ratio (GRBWR) < 0.8 is accompanied by portal inflow of > 250 mL/min/100g graft weight.[3]
- Hepatic arterial flow < 100 ml/min presents a significant risk on organ survival.[4]
- Hepatic artery flows of less than 200 ml/min following orthotopic liver transplantation increase the risk of subsequent hepatic artery thrombosis six times.[5]

LIVER HEMODYNAMICS		
TRANSPLANTED LIVER (N = 34)[1]		
Vessel	Flow: Mean ± SD (L/mm)	Range
Total Liver	2.091 ± .932	.570 - 4.540
Portal vein	1.808 ± .929	.300 - 4.500
Hepatic artery	0.268 ± 157	0.30 - 0.675

EQUIPMENT NEEDED

HT364 Dual-channel Optima®Flowmeter permits simultaneous measurements with two Flowprobes.

4 mm and 6mm FMV Vascular Handle Flowprobes are recommended for hepatic arterial flow measurements.

8-14 mm -AU COnfidence Flowprobes® provide highly accurate measurements in vessels with fluctuating flows such as the portal vein. The Probes may be left in place for extended measurements and then easily removed via a ring attached to the pliable liner that cushions and protects the vessel.

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FLOWPROBE RECOMMENDATIONS		
VESSEL	Probe Size (mm)	Probe Series
Hepatic artery	4 - 8	-FMV
Portal vein	8 - 14	-FMV, -AU
Common iliac a	8	-FMV, -FSB

8 to14 mm FMV Vascular Handle Flowprobes are recommended for portal venous flow measurements.

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Flow Protocol: Liver Transplantation cont.

Flow Measurement Protocol

Living Donor

Measure right hepatic arterial and portal venous flow before hilar dissection.

↓

Document measurements to serve as guide for expected flows in the recipient.

Recipient

Recipient Hepatic Flow

Measure hepatic blood flow
- following reperfusion
- before biliary anastomosis
- before wound closure

↓

Compare with pre-transplant hepatic arterial flow

↓ < 50 mL/min

Examine anastomosis for arterial thrombosis

↓ > 100 mL/min

Remeasure hepatic flow

Flow has increased →

Recipient Portal Flow

Measure portal blood flow
- following reperfusion
- after portal pressure measurement
- before biliary anastomosis

↓

Compare with pre-transplant portal venous flow

Flow increased up to 3 times pre-transplant portal flow →

Flow increased > 3 times pre-transplant portal flow or >250 mL/min/110 gram graft weight ↓

Reduced graft inflow by shunting portal flow away from liver[1]

↓

Remeasure portal flow

→

Document flows and save waveforms for the operative record for post-op diagnostic consideration

Troisi R, de Hemptinne B, "Clinical Relevance of Adapting Portal Vein Flow in Living Donor Liver Transplantation in Adult Patients," Liver Transplantation 2004;9(9)Suppl 1 pp S36-S41. (6884AH)

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Flow Protocol: Kidney Transplant

Intraoperative Blood Flow Measurement during Renal Transplantation

Courtesy of Anders Lundell, MD, PhD, Nils H. Persson, MD, PhD,
Dept. of Transplantation, Dept. of Surgery, Malmö General Hospital, Malmö, Sweden

Renal Arterial Flow Measurement

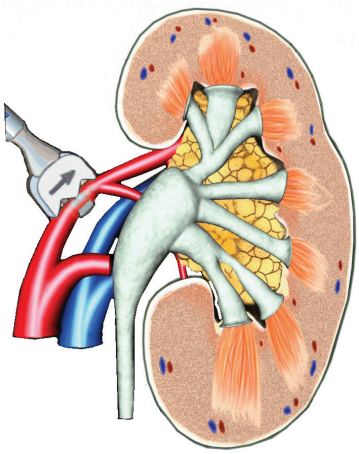
Donor: Living Donor Kidney Retrieval

The first measurement is made on the renal artery before the kidney is removed from the donor.

Recipient: Living Donor or Cadaveric Kidneys

In primary transplantations, we use the hypogastric artery for the arterial anastomosis. In re-transplantations or in cases where the internal iliac is atherosclerotic the external iliac artery is used. In selected cases, we use a flow measurement to decide which artery to use. For the venous anastomosis, the external iliac is used. No venous flow measurements are made.

After completion of the arterial and venous anastomoses, and immediately after restoration of blood flow to the kidney, but before completion of the ureteroneocystostomy, the flow in the renal artery is measured. We use a 4 or 6 mm Flowprobe which is placed, preferably, distal to the anastomosis. The space between the Probe and the vessel is filled with sterile physiological saline. Care is taken to avoid kinking the artery and to place the Probe perpendicular to the longitudinal axis of the vessel. Before the flow is recorded, we allow the flow signal to stabilize for 15-20 seconds. At the end of the operation, after the ureteroneocystostomy is completed and before the wound is closed, we make a second measurement.



Schematic of Perivascular Flowprobe measuring flow in the Renal Artery

MEAN RENAL ARTERIAL FLOWS		
TRANSPLANTED KIDNEY (N = 34)[1]		
	Flow: Cadaver Kidney (mL/mm)	Flow: Living Donor Kidney (mL/mm)
Donor		381 ± 150 SD
Post flow restoration	283 ± 148 SD	338 ± 155 SD
At end of operation	422 ± 204 SD	505 ± 177 SD

FLOWPROBE RECOMMENDATIONS		
VESSEL	Probe Size (mm)	Handle Probe Series
Renal artery	4, 6	-FMV
Renal vein	10	-FMV
External iliac artery	6, 8	-FMV
Hypogastric a	4, 6	-FMV

[1] Lundell A et al, "Impaired Renal Artery Blood Flow at Transplantation Is Correlated to Delayed Onset of Graft Function" Transplant International 1996;9(1)57-61.

[2] Bretan PN Jr et al, "Assessment of Preservation Induced Reperfusion Injury Via Intraoperative Renal Transplant Blood Flow and Endothelin Concentration Studies," J Urology 1997;158(3):714-18.

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Flow Protocol: Kidney Transplant cont.

Donor

Cadaver Kidney

No measurements

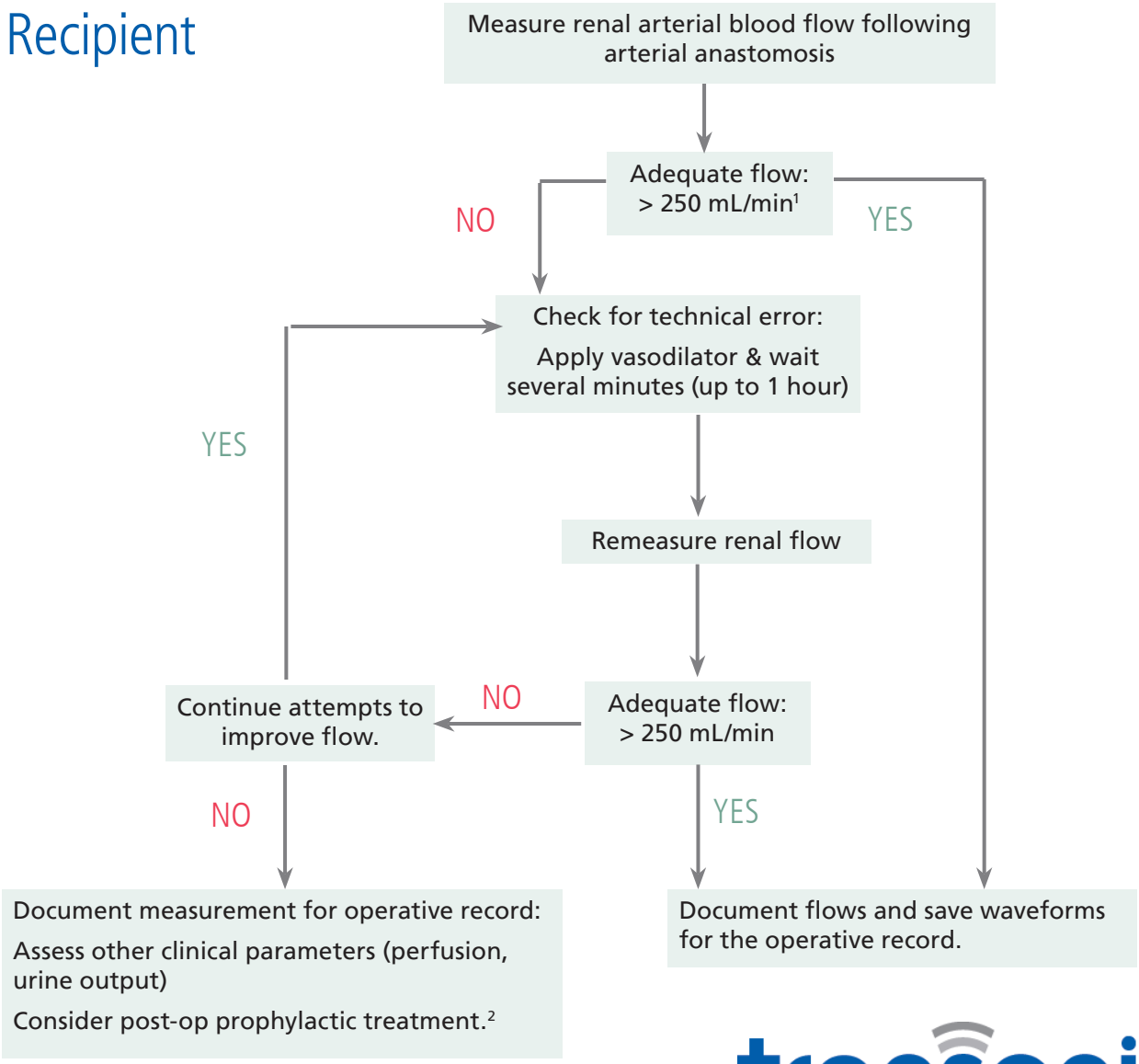
Living Donor Kidney

Measure renal arterial flow before removing the kidney

↓

Document measurements to serve as guide for expected renal flow in the recipient.

Recipient



Flow Protocol: Kidney Transplant cont.

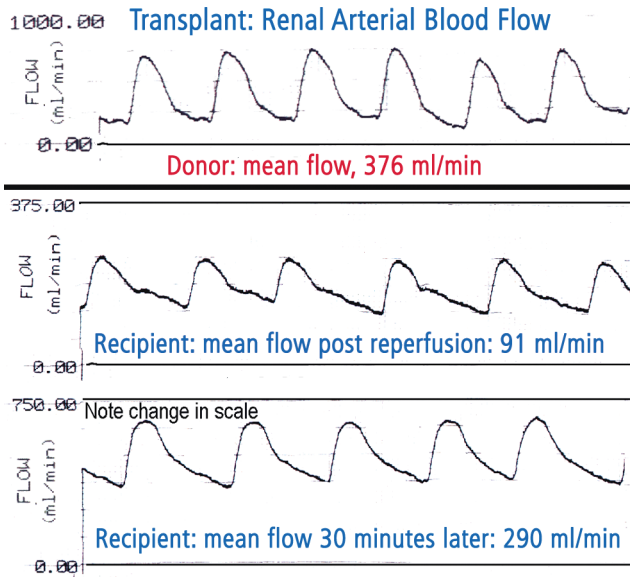


Fig. 1: The donor's renal arterial blood flow prior to excision of the kidney measured 376 mL/min. After anastomosis to the recipient's renal artery, post-reperfusion renal flow measured 91 mL/min. A second measurement was made after 30 minutes. Renal arterial flow had increased to 290 mL/min.

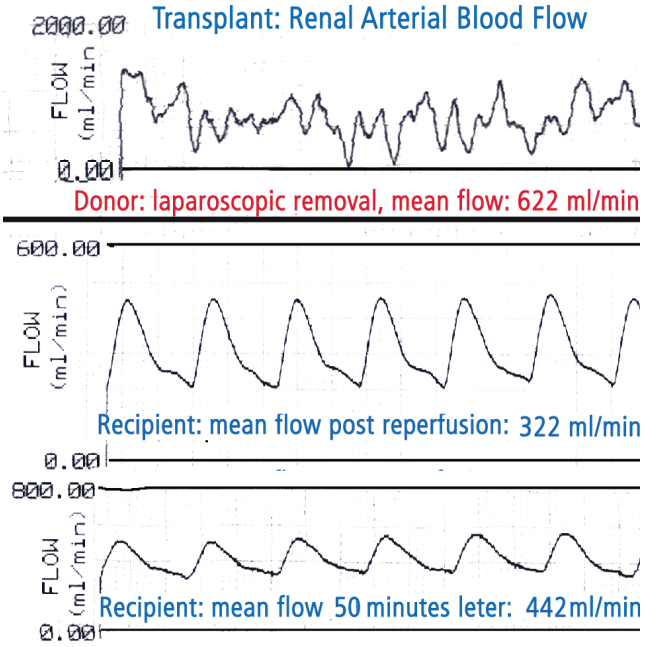


Fig. 3: Before a difficult laparoscopic removal of the kidney, the donor's renal arterial blood flow measured 622 mL/min. After anastomosis to the recipient's renal artery, renal flow post-reperfusion measured 322 mL/min. One hour later, flow had increased to 442 mL/min.

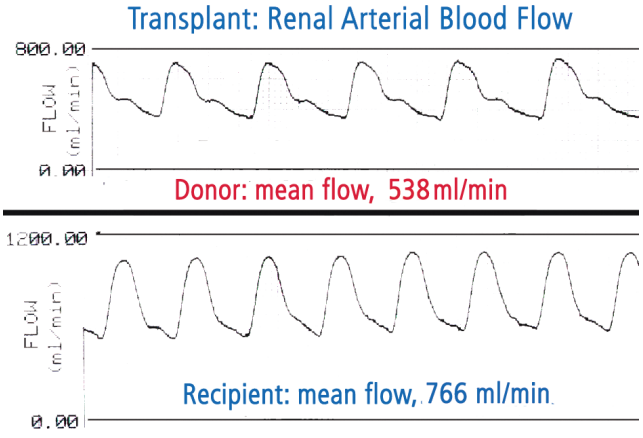


Fig. 2: The donor's renal arterial blood flow before traditional removal of the kidney measured 538 mL/min. After anastomosis to the recipient's renal artery, renal flow post reperfusion measured 766 mL/min.

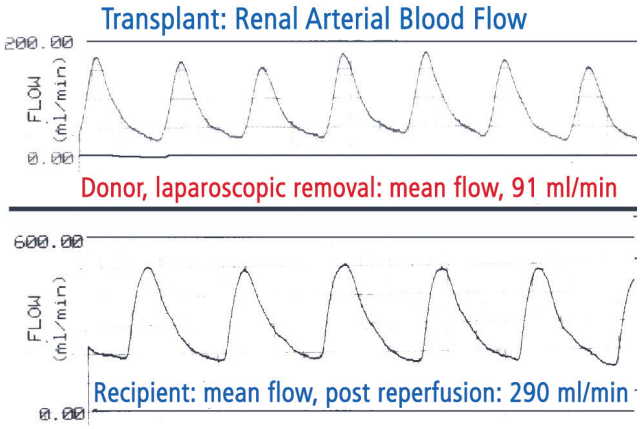


Fig. 4: Before laparoscopic removal of the kidney, the donor's renal arterial blood flow measured 91 mL/min. After anastomosis to the recipient's renal artery, renal flow post-reperfusion measured 290 mL/min.

Waveforms courtesy of Renal Transplantation Unit,
Hermann Hospital, Texas Medical Center, Houston, TX.

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Flow Protocol: Kidney Transplant cont.

Flow Measurement during Renal Transplantation

Transplant surgeries are high risk. They require a surgical team to perform at their highest level. Any tool that can inform the surgeon during these surgeries and help achieve a successful outcome is valuable. However during renal transplantation, the imperative to measure flow is subtle. Following transplantation of a renal allograft, the harvested kidney generally reperfuses turning from its grayish cast to pink and then red within seconds/minutes. When urine is released from the transplanted kidney, the allograft's functionality is verified and the success of the operation is assured. Why then is it prudent to measure flow during kidney transplantation?

Anastomotic Integrity

Intraoperative blood flow measurements provide a quick, on-the-spot quantitative assessment of the integrity of an anastomosis. Blood flow either confirms a clinical impression or alerts the team to potential problems. Knowing that flow is less than expected through an anastomosis facilitates the decision to immediately revise the anastomosis to ultimately salvage a transplanted kidney. A transit-time ultrasound Flowprobe accurately measures postreperfusion renal blood flow and offers a practical and noninvasive method for assessing renal reperfusion injury after transplantation. This can help optimize immunosuppressive strategies to maximize renal recovery."[1] Low or decreasing flow could indicate a technical error which, if left uncorrected, could endanger the transplant.[2]

Low Blood flow Indicates Delayed Graft Function

Other than a primary failure evidenced by acute rejection, delayed graft function is a major concern of renal transplantation. It has been identified to be a factor in up to 15% of all kidney transplants and doubles the risk of acute rejection and potentially reduces the overall length of organ survival. Delayed graft failure due to reperfusion injury is characterized by a depressed glomerular filtration rate (GFR) due to tubular injury, hypofiltration and drop in pressure that is necessary for reabsorption. The transplant recipient needs to be returned to dialysis. If delayed graft failure is suspected, medications can be adjusted to promote graft function.

Data for the Operative Record

Finally, flow measurement during renal transplant provides quantitative data to include in the operative record.

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Flow Protocol: Kidney/Pancreas Transplant

Intraoperative Blood Flow Measurement during Renal/Pancreas Transplantation

By 2010, more than 23,000 pancreas transplantations had been performed simultaneously with a kidney. This combined pancreas-kidney transplantation (SPK) is performed in insulin-dependent diabetes patients who have developed end-stage renal failure. The pancreas in a diabetic recipient still serves a digestive function, and it is not removed. The pancreas allograft is usually transplanted to the right iliac fossa with the kidney allograft transplanted to the contralateral left iliac fossa.

Organ Preparation

The donor pancreas, duodenum, and spleen are perfused *in situ* and harvested along with the liver by ligating the common bile duct (CBD) and the two arteries supplying the organ, the superior mesenteric artery and splenic artery (Fig. 1). The splenic artery and superior mesenteric artery stumps are then anastomosed to an iliac artery bifurcation graft harvested from the donor, so that only one arterial anastomosis must be sewn into the recipient iliac artery. The external iliac arterial limb of the graft is anastomosed to the SMA stump, and the hypogastric arterial limb to the splenic stump.

The donor's portal vein is mobilized to facilitate the venous anastomosis in the recipient. It is kept as short as possible to avoid problems with kinks and twists.

Allograft Transplant to Recipient

The pancreaticoduodenal graft is then positioned in the recipient's iliac fossa. The pancreatic arteries are anastomosed to the common or external iliac artery. The portal vein of the allograft is anastomosed to the common iliac vein or distal inferior vena cava. In the left iliac fossa, the kidney's renal artery and vein are anastomosed to the common iliac artery and vein, respectively.

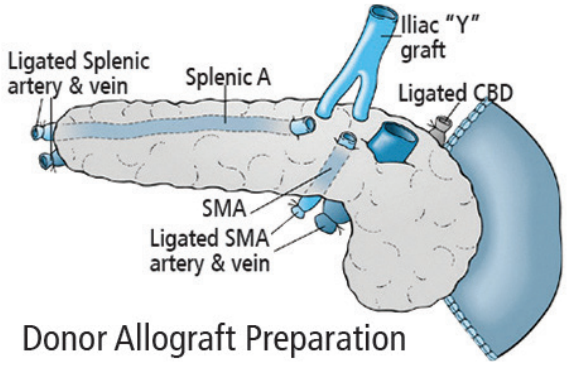


Fig. 1: Prep of donor pancreaticoduodneal allograft for transplant. The splenic artery and superior mesenteric artery stumps are anastomosed to a Y graft of the donor iliac artery. The portal vein is mobilized in the donor pancreas to facilitate the venous anastomosis in the recipient.

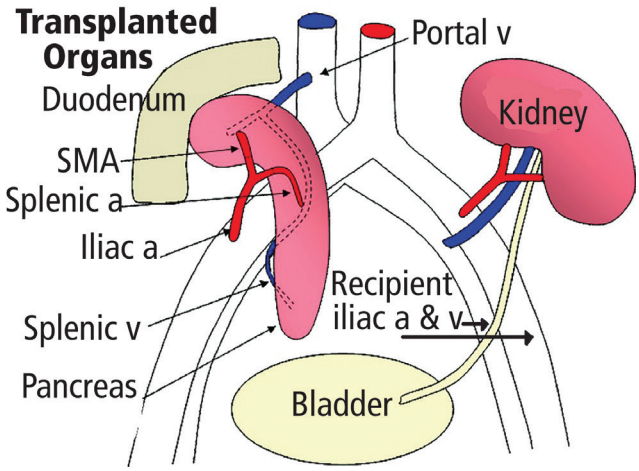


Fig. 2: Schematic of transplanted pancreas and kidney. The "Y" graft allograft iliac artery is sewn to the recipient's iliac artery and the allograft renal artery and vein are sewn into the recipient's respective renal artery and vein.

Flow Protocol: Kidney/Pancreas TX cont.

Graft Function and Patient Survival

Allograft and, ultimately, patient survival depends on functioning grafts. Graft thrombosis is the most common non-immunological cause of early graft failure (2 to 19%).[1] Thrombosis of the portal vein anastomosis is more common than an arterial thrombosis.

Anastomotic Integrity

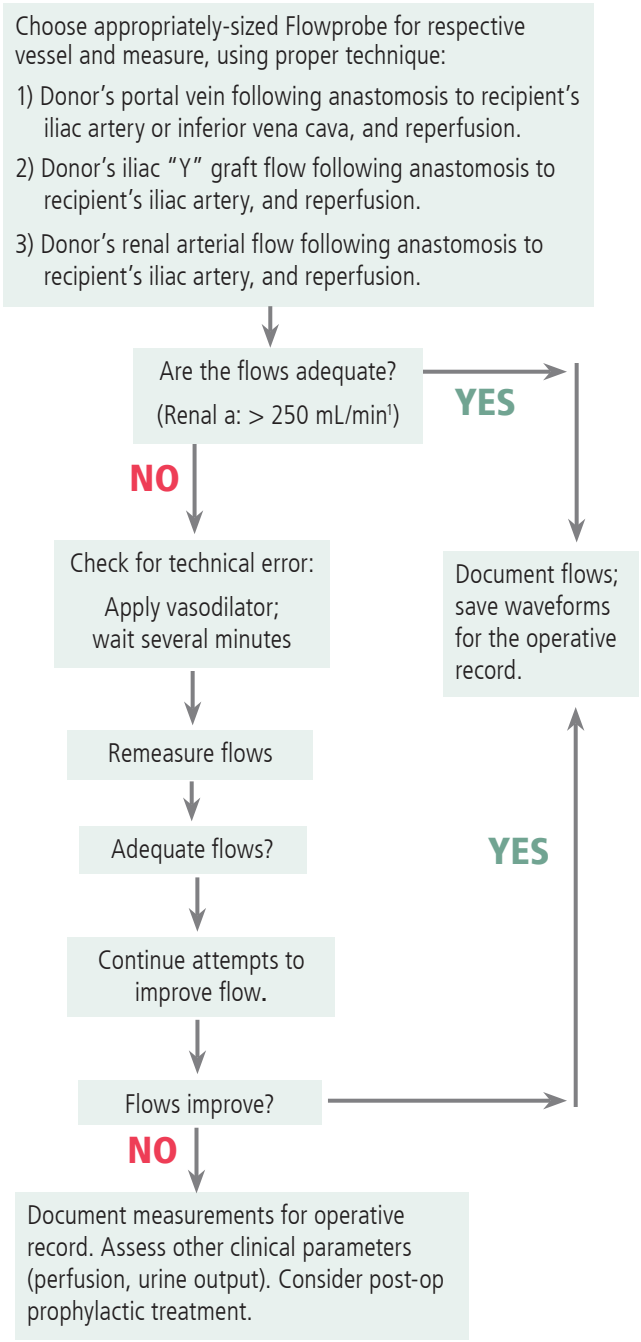
Transonic® intraoperative blood flow measurements provide quick, on-the-spot quantitative assessments of the integrity of an anastomosis. After anastomosing all the vessels during kidney/pancreas tranplantation, flow measurements will attest to the success of the surgery or, could indicate a technical error which, if left uncorrected, could endanger the transplant. Flow measurements either confirm a surgeon's clinical impressions or alerts the team to potential problems. Knowing that flow is less than expected through an anastomosis can inform a decision to immediately revise the anastomosis and ultimately salvage a allograft transplant.

Low Blood Flow Can Signal Graft Function Delays

Delayed graft function is a major concern in transplantation. It has been identified to be a factor in up to 15% of all kidney transplants and doubles the risk of acute rejection and potentially reduces the overall length of an allograft's survival. Quantitative blood measurements can also help optimize post-op prophylactic immunosuppressive strategies to maximize graft recovery.

Data for the Operative Record

Flow measurements also provide quantitative data for the operative record.



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Flow Protocol: Auto Islet Cell Transplantation

Portal Blood Flow Measurement during Auto Islet Cell Transplantation after Pancreatectomy

Flow Measurement during Islet Infusion

Excising a diseased pancreas removes not only pancreatic cells that produce digestive enzymes but also islet of Langerhans cells that produce insulin to control blood sugar. Without insulin a patient becomes diabetic and requires lifelong use of insulin to control blood sugars.

Auto islet cell transplantation takes these islet of Langerhans cells from the pancreas and transplants them to the liver to reduce the diabetic risk. To do this, the removed pancreas is processed to isolate the insulin-producing islets of Langerhans cells. The isolated cells are suspended in a solution and are then slowly infused through the splenic vein back into the patient's liver where it is hoped that they will implant, grow and produce insulin to metabolize sugar.

Typically, 800 - 1500 cc of solution is infused into the portal vein distal to the splenic vein (Fig. 2) over an extended period of time. The team may elect to infuse a small amount over 5 minutes and allow the patient to recover before resuming the infusion. Blood pressure and flow are monitored continuously and for ten minutes after the infusion is completed (Fig. 1).

Flow Measurement during Islet Infusion

Surgeons measure portal venous flow during islet cell infusion to detect any sudden decrease in flow that may foreshadow a problem with the infusion. A 10 mm to 14 mm Perivascular Flowprobe is placed on the portal vein and flow is measured continuously. The Flowprobe is chosen to comfortably encompass - but not constrict - the portal vein. If needed, saline can be used to provide acoustic contact between the vein and Flowprobe. Readings stabilize within 1-2 minutes. Wide fluctuation of measurements may indicate improper positioning of the Flowprobe with poor alignment or fat within the ultrasonic sensing window. Repositioning can normally correct this problem.

Discussion

In this high stakes auto islet cell transplantation procedure, Flowprobes provide a continuous volumetric measure of portal vein flow to inform the surgeon about the safety, fluidity and success of auto islet cell transplantation.

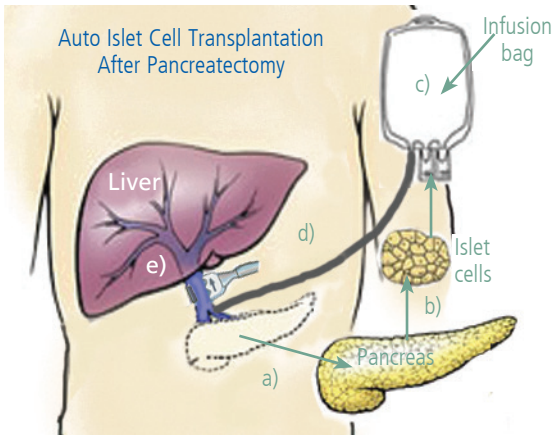

Fig. 1: Steps: Auto Islet Cell Transplantation
a) Removal of pancreas (pancreatectomy)
b) Isolation of Islet cells from removed pancreas
c) Islet cells placed in Infusion bag with solution
d) Islet cells infused into splenic vein
e) Islet cells implant in liver

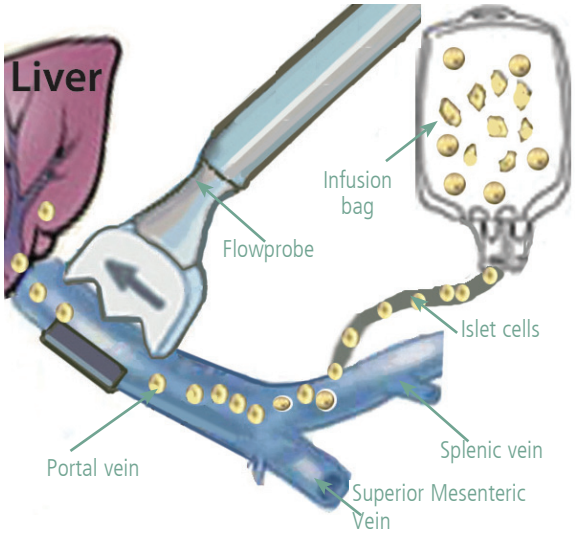

Fig. 2: Enlarged view of islet cell infusion into the splenic/portal venous system.

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Flow Protocol: Auto Islet Cell TX cont.

Equipment Needs

HT353 Single-channel Optima®Flowmeter. Acquire precise actual flow measurement quickly, easily and cost effectively.

8 mm to 14 mm FMV Vascular Handle Flowprobes are recommended for portal venous flow measurements during islet cell infusion.

COnfidence Flowprobe®

COnfidence Flowprobes® provide highly accurate measurements in vessels with fluctuating flows such as the portal vein. The Probes may be left in place for extended measurements and then easily removed via a ring attached to the pliable liner that cushions and protects the vessel.

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Flow Protocol

Intraoperative Blood Flow Measurements on Distal Spleno-renal (Warren) Shunts

Courtesy of J. Michael Henderson, M.D., F.A.C.S.,The Cleveland Clinic Foundation

Rationale

A distal spleno-renal shunt (DSRS) provides selective variceal decompression to control bleeding gastroesophageal varices, while maintaining portal hypertension and prograde portal flow to the liver (Fig. 2).

Thrombosis of distal spleno-renal shunts occur in less than 10% of patients, but usually occurs early (in the first week) and requires reoperation. Intraoperative measurement of shunt flow shows great potential to reduce the risk of this complication.

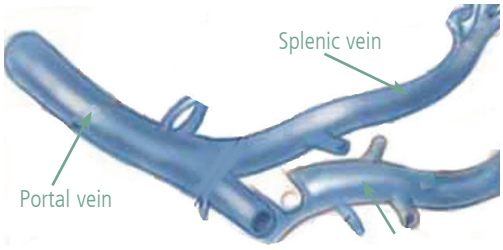

Fig. 1: Schematic of splenic vein in relation to renal vein.

Surgical Approach

On completion of the distal spleno-renal shunt anastomosis, 2-3 cm of the splenic vein is free below the pancreas before it is anastomosed to the left renal vein. A Transonic® Flowprobe can be placed on this segment of the splenic vein for volumetric flow measurement (Fig. 2). A Probe is chosen to fit comfortably around the vein without compressing it. It should lie in line with the vessel, and no tissue should be interposed. Contact is assured by immersing the field in saline. Flow measurements stabilize within one minute, and fluctuate less than ± 10%.

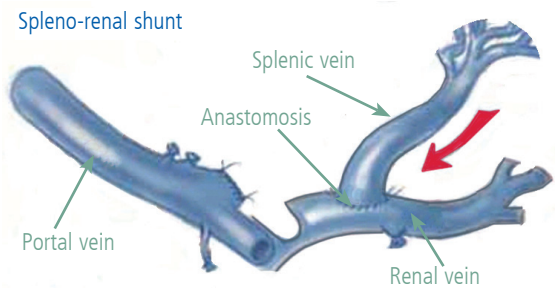

Fig. 2: Schematic of anastomosis of the splenic vein to the renal vein to create a distal Spleno-renal shunt.

Discussion

What should the flow be in a distal spleno-renal shunt? This is a high flow shunt, with volumetric flows determined largely by spleen size. There appears to be approximately 1 ml/min flow per cubic centimeter spleen volumes - i.e. a 750 cc spleen will give a shunt volumetric flow of approximately 750 ml/min.

After first removing the clamps, flow tends to be higher than it will be after 5-10 minutes when the initial hyperemia has resolved. If flow is significantly less than this approximation, a technical error should be considered.

- Is the splenic vein kinked?
- Is there a problem with the anastomosis?

Now is the time to identify and correct a technical problem: transit-time ultrasound Flowprobes offer a method for identifying low flow in this shunt.

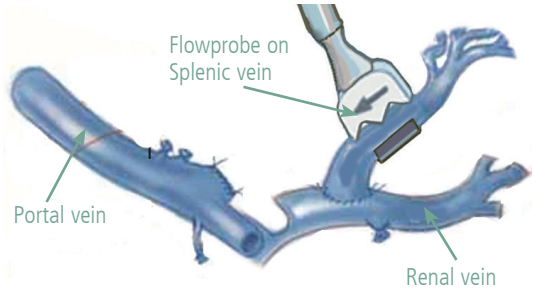

Fig.3: Flowprobe measuring flow in the splenic vein following anastomosis of the splenic vein to the renal vein.

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Flow Protocol: Distal Spleno-renal Shunt cont.

Background

Alcoholic (Laennec's) cirrhosis of the liver is a common cause of portal hypertension. Portal hypertension extends to esophageal veins via gastric, splenic and gastroepiploic veins. When bulging esophageal varices are eroded by food passage through the esophagus, massive bleeding can result.

In 40% of U.S. cirrhosis patients, portal hypertension causes acute bleeding from the varices of the esophagus or stomach. This variceal bleeding accounts for one-third of all deaths related to cirrhosis. A significant bleeding episode is fatal 50% of the time. Of those surviving, two-thirds will rebleed. It is therefore crucial to first arrest the acute bleeding episode and then treat the portal hypertension.

One way to treat portal hypertension is through portal decompression via a surgically-created distal spleno-renal (DSRS) or Warren shunt.

A distal spleno-renal shunt is a high volume shunt that diverts splenic venous flow from the portal venous system to the renal venous system. An enlarged spleen (splenomegaly) is common in patients with end-stage-liver disease. A distal spleno-renal shunt provides good long-term control of variceal bleeding.

How Is a Distal Spleno-renal Shunt Constructed?

The abdomen is opened. The stomach and pancreas are elevated to expose the splenic vein which is isolated and mobilized by detaching it close to its junction with the portal vein. The vein is then reattached to the renal vein via an end-to-side anastomosis (Figs. 2,3). Intraoperative flow measurement during creation of a DSRS ensures good shunt flow without kinking of the vein or a problem with the anastomosis.