Pancreas-Kidney Transplantation: When and how do the checks with Doppler ultrasound

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Learning objectives

• To explain the possible locations, orientations, relationships and physiology of the new transplanted organ.

• To review the protocol review, methodology and temporal protocol of Doppler ultrasound of patients transplanted pancreas-kidney (TxPK).

• To review the radiological findings on Doppler ultrasound, indicating good and/or poor outcome.

• A useful radiological report.
Background

Diabetes mellitus (DM) affects 6% of the population, constituting a major global public health problem, as it is one of the three leading causes of morbidity and mortality in adults.

Pancreas transplantation (TxP) is currently the only treatment that restores euglycemia state, with a long-term normalization of glycated hemoglobin levels. Today is shown that effective control of the metabolism of carbohydrate and lipid can only be achieved with TxP.

According to the International Pancreas Transplant Registry were performed approximately 35,000 pancreas transplants, more than 24,000 in the US and almost 12,000 outside the US.

Combined pancreas and kidney transplantation seeks to resolve renal failure and insulin deficiency, thus improving life expectancy.

The pancreas-kidney transplant is recommended for insulin dependent diabetic patients with end stage renal disease treatment.

Survival of kidney-pancreas receptors is higher than that of single kidney recipients.

Achieved normoglycemia with pancreas-kidney transplant is able to stabilize lesions retinopathy, neuropathy improving and preventing the development of nephropathy in the graft.

Combined kidney pancreas transplantation has been shown to decrease the risk of death by half, when compared with DM on the waiting list for dialysis (RR 0.4 to 5 years of follow-up).

At present pancreatic transplantation is contemplated in three situations:

1. Combined with simultaneous kidney transplantation, dialysis patients with diabetic nephropathy: this is the clearest and most frequent indication, grouping more than 85% of transplants. (can be done preventively before starting dialysis).
2. Pancreatic transplantation in patients with renal Tx prior functioning, at least three years: meets 10% of transplants.
3. **Isolated pancreas transplantation** in patients without established nephropathy, but with longstanding diabetes, difficult to control and frequent episodes of hypoglycemia: is the most controversial indication, comprising 5% of the indications for transplantation.

**PANCREAS. Transplanted organs (pancreas-kidney) location, orientation, relationships, physiology.**

The pancreas allograft is harvested with the donor duodenum and vascular support. It is typically placed in the right lower peritoneal cavity or pelvis.

**Arterial Supply:** The pancreas transplant receives arterial inflow from two sources: the donor superior mesenteric artery (SMA), which supplies the head of the pancreas via the inferior pancreaticoduodenal artery; and the donor splenic artery, which supplies the body and tail. The donor common, internal, and external iliac arteries are attached to the donor SMA and splenic arteries, forming a Y graft. The common iliac artery portion is then anastomosed to the recipient common iliac artery or external iliac artery, with a variable graft length that depends on venous-duodenal drainage.

**Venous Drainage:** Venous outflow that contains pancreatic endocrine secretions may be drained via the recipient portal or systemic venous system. The current technique involves an anastomosis between the donor portal vein, which functions as the main graft vein, and the recipient superior mesenteric vein. Systemic venous drainage involves an anastomosis of the graft vein to the recipient iliac vein or, to the inferior vena cava.

**Exocrine Secretions:** The donor duodenum containing the ampulla of Vater is harvested with the donor pancreas. Pancreatic exocrine secretions may be drained to the gastrointestinal tract (enteric drainage) or the bladder (bladder drainage) via the donor duodenum. Enteric exocrine drainage is used most commonly and is achieved by means of an anastomosis between the donor duodenal stump and the recipient small bowel, with or without the creation of a Roux-en-Y loop. Enteric-drained transplants are usually located in the midabdomen to the right of midline, with the head of the pancreas situated cranially for portal venous drainage or caudally for systemic venous drainage. Bladder drainage of exocrine secretions is achieved by an anastomosis between the donor duodenal stump and the superior aspect of the bladder. Bladder-drained allografts are usually located in the right side of the pelvis, superior to the bladder, with the head of the pancreas directed caudally. One advantage of bladder drainage is that urinary amylase may be used to monitor graft function.
KIDNEY. Transplanted organs (pancreas-kidney) location, orientation, relationships, physiology.

The renal transplant is placed extraperitoneally within the iliac fossa. The right iliac fossa is preferred because the vascular anastomosis with the right iliac vein is more straightforward, given its more superficial and horizontal course in the pelvis.

The arterial anastomosis typically involves an end-to-side anastomosis of the donor renal artery to the recipient external iliac artery. In the presence of multiple main renal arteries, these can be anastomosed separately or en bloc as a Carrel patch. Occasionally the internal iliac artery can be divided in the recipient and mobilized for anastomosis to accessory vessels.

The venous anastomosis involves an end-to-side anastomosis between the donor renal vein and the recipient external iliac vein.

A ureteroneocystostomy is performed with implantation of the donor ureter into the bladder dome.
Fig. 1

Fig. 2

Findings and procedure details

Doppler US will be done to the organs transplanted:

- Every 24 hours the first 3 days.
- Every 7 days until they reach one month post transplant.
- Controls will be installed according to the analytic patient.

KIDNEY US Doppler

Color Doppler ultrasound shows the iliac vessels and the perfusion of the kidneys. The pulsed Doppler is used to predict the flow resistance of the parenchyma (resistance index, pulsatility index) and patterns of intrarenal Doppler waves. This initial test is very useful in early detection of complications and to obtain baseline parameters for monitoring.

The perfusion pattern of a normal kidney graft, which because it is of low impedance vascular beds diastolic flow is always anterograde and RI is less than 0.7. Infusion rates are conditioned by many factors, among which are: the blood pressure, hypotensive drugs, use of drugs, the existence of collections that compress the graft and the degree of atheroma of the donor and recipient.

- **GRAFT DYSFUNCTION**: Increased RI (> 0.7) reaches the value of 1 when the systolic flow disappears because then the numerator and denominator of the formula for RI are equal (RI = SV-DV / SV) was considered specific for acute rejection. RI values > 0.8 and > 0.9 were attributed to positive predictive values of 82% and 100% respectively, while RI < 0.7 has a negative predictive value of 98%. The existence since the immediate post-kidney transplant with elevated RI in a nonfunctioning graft suggestive of acute tubular necrosis.

- **RENAral ARTERY STENOSIS** (1-23%) is one of the most common vascular complications. Color Doppler ultrasound is the initial most useful technique for suspected renal artery stenosis. Typically seen color aliasing in the stenotic segment, an increase in peak systolic velocity (> 230 cm/s) in the stenosis and shear rate between and prestenotic stenotic segment of the artery of more than 2:1. The intrarenal Doppler waves lose their normal morphology with early systolic peak, accompanied by decreases in RI <0.5 in the "type tardus-parvus wave" post-stenotic segment and fall of acceleration in the arcuate artery, prolonged acceleration time (> 0.80 s) or decrease in acceleration < 390 cm/s. They have been described as the
characteristic pattern of a hemodynamically significant stenosis, that is with a light reduction > 50%.

- The **ARTERIAL GRAFT THROMBOSIS** is a rare cause in the simple transplant adult, it occurs more frequently in the early postoperative period. Absence of flow distal to the thrombus, or in the intrarenal vessels is appreciated. If the diagnosis is delayed, graft loss is inevitable.

- Kidney with **VENOUS THROMBOSIS** is increased in size by ultrasound, with loss of echogenicity and absence of venous flow Doppler ultrasound and Doppler blood flow reversed prolonged renal artery or aorta in spectral Doppler ultrasound. The segmental infarction is caused by thrombosis of any of the intrarenal arterial branches or a polar branch. In ultrasound imaging can be seen as a hypoechoic focal echogenic area that can have edges. Perfusion defects are better with Doppler ultrasound showing no segmental vascularized areas detected.

- Other vascular complications such as arteriovenous **fistulas or pseudoaneurysms**, are usually secondary to the biopsies and demonstrated with color and pulsed Doppler ultrasound with bidirectional flow pattern on the neck of the aneurysm and turbulent flow in fistulas.

**PANCREAS US Doppler**

US is routinely used in the initial evaluation of the transplanted pancreas. In addition to grayscale demonstration of the allograft and peripancreatic fluid collections, color and duplex Doppler imaging can document perfusion and help in evaluation for vascular complications.

When direct visualization of the pancreas transplant is difficult, color and power Doppler imaging can help identify parenchymal and graft vessel flow, thereby indirectly localizing the pancreas.

Color and power Doppler US are essential for demonstrating pancreas transplant perfusion and vascular anatomy; the Y arterial graft, graft vein, and splenic artery and vein are usually visible. Arterial waveforms normally show a rapid systolic upstroke and continuous diastolic blood flow, whereas venous structures demonstrate a monophasic waveform within an anechoic lumen.
The use of resistive indexes (resistive index = peak systolic velocity - end diastolic velocity / systolic velocity) has been well established for predicting acute rejection of renal grafts. However, because the pancreatic graft lacks a capsule, an edematous pancreatic graft may not possess adequate intraparenchymal pressure to produce a reliable measurement of vascular resistance. Unlike renal transplants for which specific resistive index values have been proved to be accurate predictors of acute rejection, no reliable resistive index measurement has been established for at-risk pancreatic grafts.

Often, the splenic artery and vein can be readily identified. These structures end blindly and thus have an increased possibility of becoming thrombosed. Consequently, Doppler sonography has been particularly important in detecting vascular complications such as thrombosis, anastomotic strictures, and pseudoaneurysm formation.

- **GRAFT REJECTION.** Because color Doppler US usually demonstrates major vessel patency, it will help exclude graft thrombosis as a cause of poor function but cannot help differentiate pancreatitis from rejection. Resistive indices have not been useful for diagnosing acute rejection. In practice, the major roles of US are to exclude thrombosis and to guide biopsy. Severe acute rejection or hyperacute rejection may culminate in vascular thrombosis and infarction and may be mistaken for primary thrombosis.

- **ARTERY STENOSIS:** aliasing is detected in the stenotic segment. Increased pre stenotic peak systolic velocity. And post stenotic speed decrease.

- **US findings of vascular THROMBOSIS** depend on the degree and location of the clot. These include echogenic intraluminal thrombus at gray-scale US and absence of vascular flow in the vessel and possibly throughout the parenchyma at color and pulsed Doppler US. With venous thrombosis, arterial waveforms typically show a high-resistance pattern with reversal of diastolic flow. If pancreatic infarction results, the transplant will appear enlarged and hypoechoic without color Doppler flow. With chronic thrombosis, the allograft may be atrophic and difficult to see with US. It typically demonstrates increased echogenicity and decreased perfusion.

- At color Doppler US, a **pseudoaneurysm** shows internal swirling blood flow with a characteristic to-and-fro waveform in the feeding vessel. **Arteriovenous fistulas** also vary in size and may be invisible on grayscale images. Color Doppler US shows color aliasing and a characteristic high-velocity low resistance Doppler waveform with pulsatile flow in the draining vein if the fistula is large.
US DOPPLER. A useful radiological report

Pancreas and kidney transplant:

1. Position
2. Orientation
3. Relations
4. Vascularization (Describe RI and flow wave morphology)
5. Arterial supply
6. Parenchyma
7. Venous Drainage
**Fig. 3:** Color Doppler: Normal perfusion of the renal parenchyma uniformly.
Fig. 4: Pulsed Doppler intrarenal arteries (Arcuate): Wave normal flow of low resistance.
Fig. 5: The perfusion pattern of a normal kidney graft (low impedance vascular beds diastolic flow is always anterograde and RI is less than 0.7)

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Fig. 6: The RENAL ARTERY STENOSIS. Aliasing in the stenotic segment, an increase in peak systolic velocity (> 230 cm/s) RI > 0.7.
Fig. 7: ARTERIAL GRAFT THROMBOSIS, Absence of flow distal to the thrombus in superior renal pole.

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Fig. 8: Normal blood supply of superior mesenteric artery of the donor pancreas transplant.

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Fig. 9: Normal venous drainage of the transplanted pancreas to the portal venous system.

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**Fig. 10:** Pulsed Doppler of superior mesenteric artery that supplies blood to the donor pancreas transplanted. Presents low resistance flow.

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Fig. 11: Vascular THROMBOSIS, with absence of vascular flow in the vessel and in the parenchyma at color Doppler US. The transplant appear enlarged and hypoechoic without color Doppler flow.

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Conclusion

- TxP is currently the only treatment that restores euglycemia.
- Ultrasound is the best technique for control in patients who have been TxPK.
- Color and Doppler US can document and help in evaluation for vascular complications.
- This initial test is very useful in early detection of complications and to obtain baseline parameters for monitoring.
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