

Received:  
26 January 2020

Revised:  
24 January 2021

Accepted:  
08 February 2021

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Cite this article as:

Hameed M, Hameed S, Harvey C, Moser S, Muthusamy A. Imaging in whole organ pancreatic transplants and a multimodality review of its complications. *Br J Radiol* 2021; **94**: 20200106.

## PICTORIAL REVIEW

# Imaging in whole organ pancreatic transplants and a multimodality review of its complications

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### ABSTRACT

This pictorial review will describe the normal anatomy of whole organ pancreatic transplants and the common surgical variants with which the radiologist should be familiar. Complications may be divided into (1) vascular: arterial occlusion and stenosis, venous thrombosis, pseudoaneurysms and arteriovenous fistulae, (2) parenchymal complications such as pancreatitis and the variety of peripancreatic collections, and (3) enteric complications including leak and fistula formation. The radiologist plays a crucial role in the initial assessment of graft anatomy and perfusion, prompt diagnosis, and increasingly, in the management of complications.

### INTRODUCTION

Vascularised whole organ pancreatic transplantation has revolutionised the management of selected patients with severe diabetes-related complications. The transplants are performed most commonly as part of simultaneous pancreas-kidney transplant (SPK), or pancreas transplant after a successful kidney transplant (PAK), or less commonly as pancreas transplant alone. Over 2,000 pancreatic transplants are performed worldwide each year.<sup>1</sup>

Pancreatic grafts have enteric, vascular and parenchymal complications, which have been reported to occur in up to 55% of pancreas transplants in some series.<sup>2</sup>

The radiologist is pivotal in providing information on graft perfusion and in the early diagnosis of complications during the post-operative period. Hence, understanding the relevant surgical anatomy, which may be complex, is paramount. To this end, a multimodality approach is necessary. Ultrasound is typically the first-line imaging modality; however, there is a significant role for cross-section imaging as well as interventional radiology.

### PANCREATIC TRANSPLANT ANATOMY AND SURGICAL VARIANTS

Pancreatic transplant anatomy may be variable with several common variations in surgical approach. The pancreatic allograft, associated vasculature and duodenum are procured and transplanted in the peritoneal cavity, typically the right iliac fossa. Two of the most prevalent approaches are systemic venous-enteric drainage (Figure 1a) and portal venous-enteric drainage (Figure 1b). Systemic venous-bladder drainage (Figure 1c) was in vogue in the 1990s and has found some resurgence in re-transplants, and in solitary pancreas transplants.<sup>3-5</sup>

### ARTERIAL SUPPLY

The donor superior mesenteric artery (SMA) and splenic arteries are anastomosed to the donor external and internal iliac arteries, using the donor common iliac artery as the inflow (Y graft). The donor common iliac artery component is often anastomosed to the recipient common or external iliac artery (Figure 1), although technical variations can occur depending on previous transplants, calcific or occlusive disease in the recipient etc. Hence, direct communication with the implanting surgical team is helpful in identifying the relevant anatomy.

Figure 1. Illustrations depicting the donor superior mesenteric artery (dSMA) supplying the pancreatic graft head and donor splenic artery (dSA) supplying the graft body and tail. These vessels are then anastomosed to the donor common, internal or external iliac arteries to form the Y graft. The Y graft is most commonly attached to the recipient common iliac artery (rCIA). The donor superior mesenteric vein (dSMV) and splenic veins (dSV) form the main transplant donor portal vein (dPV). (a) Systemic venous and enteric exocrine drainage: The most common configuration where the donor portal vein anastomosis is with the recipient inferior vena cava (rIVC, most commonly), external or common iliac veins. Exocrine drainage is via recipient small bowel anastomosis to the donor duodenum. (b) Portal venous-enteric drainage where the donor PV is anastomosed to the recipient SMV (rSMV) and drainage of the duodenal stump is via a small bowel loop. (c) Systemic venous-bladder drainage where the main graft PV vein is attached to the recipient common or external iliac vein or IVC (here common iliac vein; rCIV). The donor duodenum is anastomosed to the recipient urinary bladder.

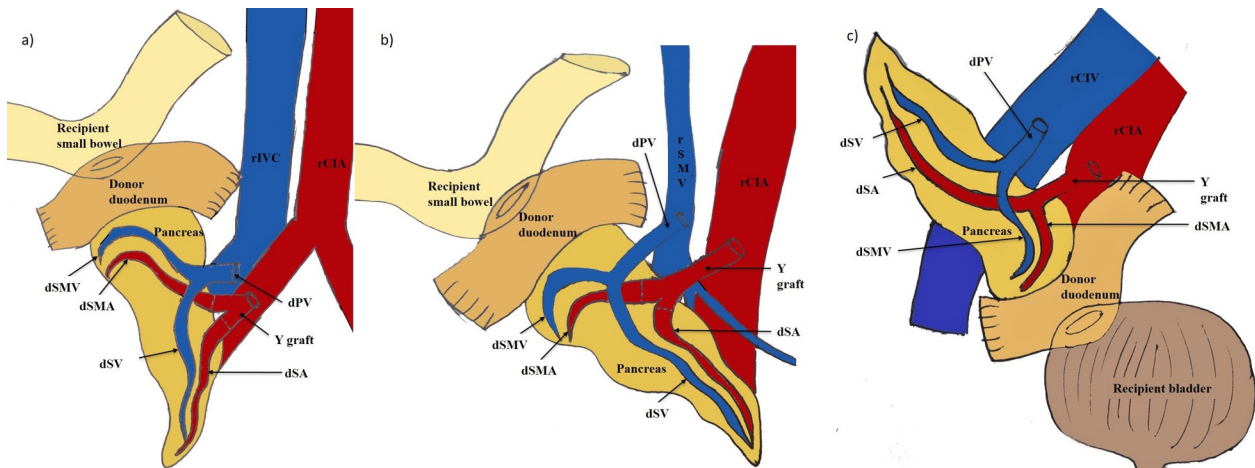
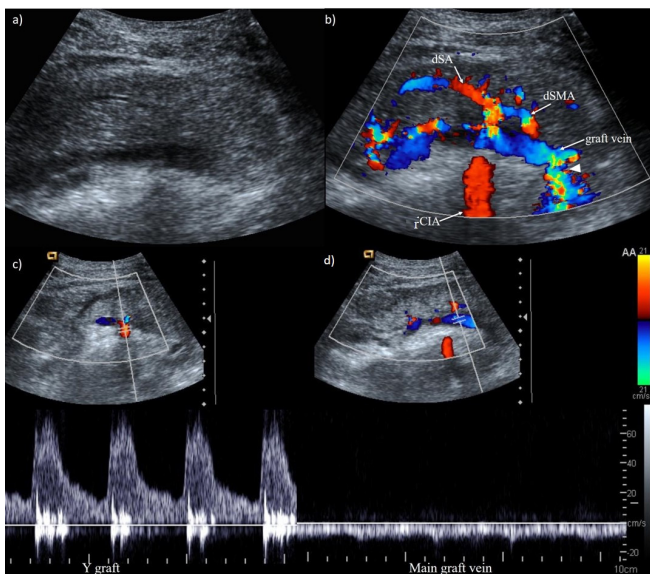


Figure 2. (a) Longitudinal conventional B-mode ultrasound demonstrating the usual hypoechoic pancreas parenchyma and non-dilated pancreatic duct. (b) Longitudinal colour Doppler ultrasound image showing the components of the donor arterial Y graft (dSMA and splenic artery; dSA, and common iliac artery; dCIA), the recipient common iliac artery (rCIA), main graft vein and its anastomosis to the systemic venous system (arrowhead) are also seen. (c) Normal colour Doppler waveforms from the arterial Y-graft; note the forward flow during diastole, and d) main graft portal vein.



**VENOUS DRAINAGE**

This may be via the systemic venous or portal venous circulations. In the former, an anastomosis is formed between donor portal vein, which receives the donor superior mesenteric (SMV) and splenic veins, and the recipient common or external iliac veins or inferior vena cava (Figure 1a). A less common alternative is portal venous drainage where the donor portal vein is attached to recipient SMV (Figure 1b).<sup>3</sup>

**EXOCRINE DRAINAGE**

Pancreatic exocrine outflow is most often through enteric drainage via anastomosis of the donor duodenum to the recipient small bowel, typically jejunum with or without a Roux-en-Y loop (Figure 1a, b), or rarely to the recipient duodenum. Alternatively, the duodenal stump may be joined to the recipient urinary bladder (Figure 1).<sup>3</sup>

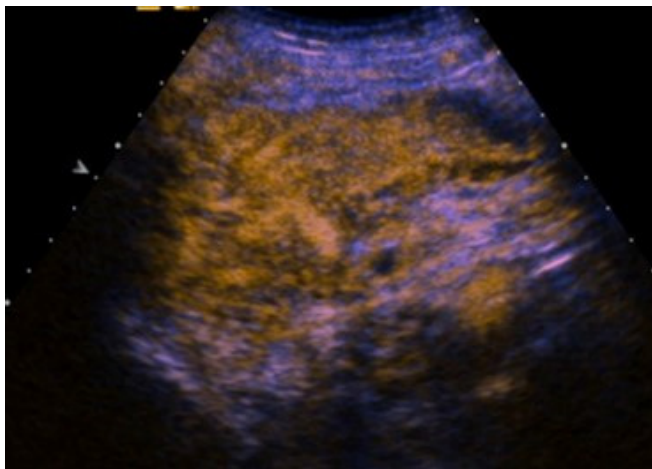
**NORMAL TRANSPLANT POST-OPERATIVE APPEARANCES**

**Ultrasound**

Ultrasound is usually the first-line imaging modality at our institution, both in the immediate post-operative period and initial assessment of later complications.<sup>4</sup> B-mode ultrasound may be used to assess the pancreatic parenchyma (Figure 2a) and for peri-pancreatic collections.

Colour or power Doppler ultrasound can assess graft perfusion and delineate vascular anatomy and patency (Figure 2b and c). The components of the arterial Y graft are usually apparent and a low resistance, triphasic arterial waveform obtained, which

Figure 3. Normal transplant appearances on late contrast-enhanced ultrasound (intravenous SonoVue, (Bracco, Italy) showing uniform parenchymal enhancement.



should demonstrate forward flow, even in diastole (Figure 2c). Unlike renal transplants, use of resistive indices is limited in pancreatic transplant rejection due to a non-restrictive capsule with no corresponding rise in intra-graft pressure with oedema.<sup>5</sup> Contrast-enhanced ultrasound is useful in evaluating perfusion (Figure 3). The transplant vein demonstrates a continuous waveform on colour Doppler (Figure 2c, Table 1).

### COMPUTED TOMOGRAPHY

CT is useful in the assessment of parenchymal and enteric complications, including extent of fluid collections. Individual arterial and venous vascular components may also be assessed (Figure 4), particularly if ultrasound is inconclusive; partial arterial or venous thrombosis may be identified.

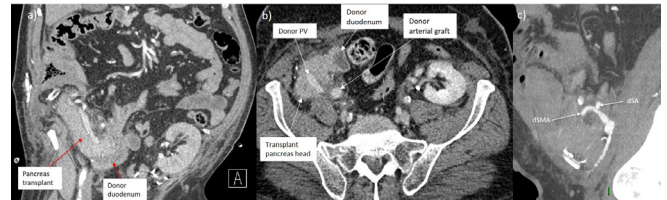
### MAGNETIC RESONANCE IMAGING

MR angiogram (MRA) may be used for arterial and venous complications (Figure 5).<sup>6</sup> This may show arterial occlusions, stenoses and aneurysms, and arteriovenous fistulae. MRA may help in the early postoperative period if there is concern about contrast load in a concurrent transplanted kidney.

### POST-OPERATIVE COMPLICATIONS: (1) VASCULAR

Up to 30% of patients have venous or arterial thrombosis.<sup>2,7-9</sup>

Figure 4. (a) coronal and b) axial portal venous phase CT images demonstrating the uniformly enhancing pancreatic graft parenchyma, donor duodenum and donor portal vein (PV). There is a left iliac fossa renal transplant. (c) Coronal arterial phase CT reconstruction of the donor superior mesenteric (dSMA) and splenic arterial (dSA) components of the Y graft.



Vascular thromboses are usually initially demonstrated on ultrasound as reduced parenchymal vascularity, altered arterial or venous Doppler waveform with the thrombus often directly visualised (Figures 6a, 7a).

To avoid re-laparotomy, there is an increasing role for radiological endoluminal treatment with angioplasty/stenting and embolisation, particularly in the absence of established necrosis (Figure 8c).<sup>10</sup>

### Y GRAFT ARTERIAL OCCLUSION AND STENOSIS

Arterial thrombosis usually occurs within the first few weeks post-transplant causing graft failure/dysfunction.<sup>7,8</sup> Causes include rejection, smaller vessels, low flow states, pancreatitis, infection, faulty surgical technique and kinking.<sup>6-8</sup> Arterial stenosis can be difficult to detect on ultrasound, only typically manifesting as a high peak systolic velocity or turbulent flow especially at anastomoses. Definite diagnosis is more often made on MR or conventional angiography (Figures 8 and 9). A portal venous-enteric approach necessitates a longer Y graft due to the relatively cranially positioned transplant and is at particular risk. Endoluminal intervention may achieve reperfusion and rescue the graft in arterial thrombosis but often pancreatectomy is necessary. For significant stenoses angioplasty is useful.<sup>6-8</sup>

### VENOUS THROMBOSIS

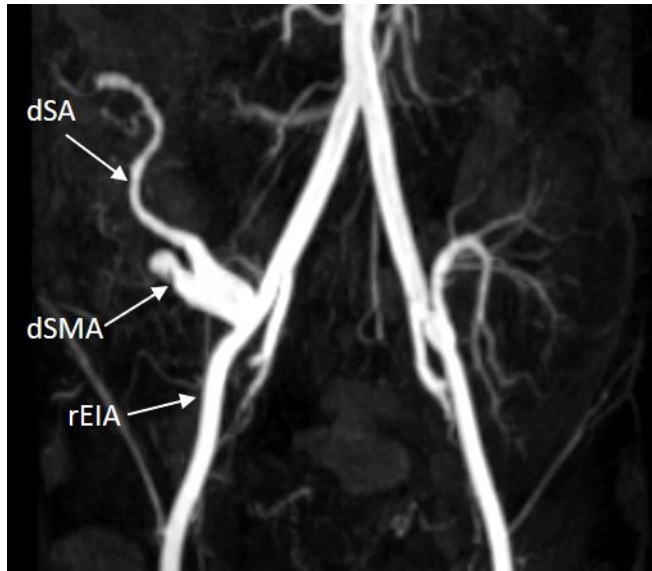
Venous thrombosis is one of the most frequent reasons for graft failure (Figure 7).<sup>2,9</sup> The graft may appear enlarged and heterogeneous. In addition to loss of the normal monophasic venous waveform on colour Doppler, there may be reversal of

Table 1. Practical tips for ultrasound

Ultrasound tips
<ul style="list-style-type: none"> <li>Initially, use a 4–6 MHz curvilinear probe to gain a wider field of view and detect any deep collections. Later, a high-frequency probe (9 MHz) may help as the graft is often superficial and can resemble bowel or fat.</li> <li>Moderate distension of the urinary bladder can displace and prevent bowel loops from obscuring the intraperitoneal transplant; this is particularly an issue if the graft is anastomosed to the CIA/IVC.</li> <li>Locate the external iliac vein and arterial anastomosis to help orientate yourself and assess the arterial Y graft.</li> <li>SMA may be too small to recognise; use arterial waveforms in the pancreatic head to infer patency.</li> <li>Although useful for assessing any concurrent renal transplant, resistive indices are not helpful to detect pancreatic graft dysfunction (thin, non-constrictive capsule and so intra-graft pressure does not increase with oedema/rejection); contrast-enhanced US or microflow imaging is best to assess perfusion.</li> </ul>

CIA, Common iliac artery; IVC, Inferior vena cava; SMA, Superior mesenteric artery.

Figure 5. Three-dimensional maximum intensity projection MR angiogram showing the donor arterial Y graft (donor splenic artery; dSA, and donor superior mesenteric artery; dSMA). Recipient external iliac artery; rEIA. Note the left iliac fossa renal transplant.



the diastolic flow in the arterial Y graft waveform. The thrombus may be seen as an intraluminal filling defect on US, CT or MRI. Anticoagulation is the usual management but endovascular intervention may be used in short-segment thrombosis.<sup>7</sup>

### PSEUDOANEURYSM AND ARTERIOVENOUS FISTULA

Pseudoaneurysms (Figures 10–12) and arteriovenous fistulae (Figures 13 and 14) are less common vascular complications. There may be multiple aetiological factors including surgical trauma, post-biopsy, graft infection and pancreatitis. Pseudoaneurysms are often associated with bacterial or fungal infections of the arterial conduit or anastomotic suture lines. It is important to detect these complications early due to the risk of subsequent severe bleeding and graft failure. A surgical or endovascular (Figure 12) intervention with a covered stent and/or embolisation may be indicated.<sup>11–13</sup>

Figure 6. Arterial complications: (a) Longitudinal ultrasound image demonstrates an echogenic filling defect corresponding to thrombus in the donor-splenic artery limb of the Y graft (asterisk). (b, c) Axial arterial phase CT showing thrombus within the Y graft (arrowed). Note the enhancing left iliac fossa renal transplant.



Figure 7. (a) Ultrasound readily appreciates the absence of flow on colour Doppler in the expanded transplant portal vein (NB it can be challenging to delineate individual donor venous components). (b, c) Contrast-enhanced CT images demonstrating non-occlusive thrombus in the donor-splenic vein and SMV extending to the recipient venous anastomosis (arrowed). The pancreatic parenchyma is mildly swollen, however, remains uniformly enhancing. In (c), there is a failed, poorly enhancing right iliac fossa renal transplant.



### POST-OPERATIVE COMPLICATIONS: (2) PARENCHYMAL

#### Peri-transplant collections

Collections can include haematoma, seroma, abscesses, pseudocyst, urinoma, lymphocele and rarely, from duct disruption.<sup>2,4,14,15</sup> The type of collection is often not discernible on imaging. However, high density or intensity on CT and T1W MRI, respectively, points to haemorrhage/haematoma and the presence of gas in the collection may be seen in abscesses and anastomotic leaks (Figure 15). Imaging is essential in documenting the size and extent of the collection as well for vascular compression and guiding drainage.<sup>2,4,14,15</sup>

#### Pancreatitis

Pancreatitis is very common in the early post-operative phase occurring in up to 40% of patients with a higher rate seen in the bladder drainage approach.<sup>2,7,9</sup> It is often self-limiting but can result in graft dysfunction. Imaging findings most commonly include peri-pancreatic fat stranding and fluid, enlargement and heterogeneity of the graft, as well as the sequelae of pancreatitis (Figure 16). Serum amylase is unreliable as a marker of severe pancreatitis and commonly raised in the early postoperative phase. Management is usually conservative with parenteral nutrition, nil by mouth and intravenous fluids.

Figure 8. (a) Coronal maximum intensity projection image from MRA shows a tight stenosis of the Y graft (arrowhead). (b) Catheter angiogram demonstrating the tight stenosis of the Y graft (arrowhead). (c) Balloon angioplasty was subsequently performed via selective catheterisation of the transplant Y graft with marked improvement.

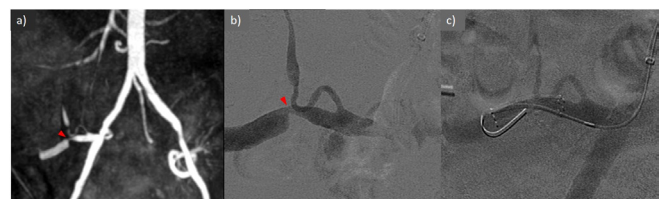
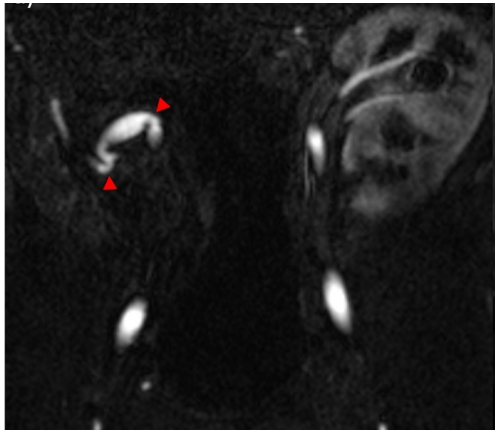


Figure 9. Three-dimensional MRA shows a tortuous SMA branch with two kinks resulting in significant stenosis.



### POST-OPERATIVE COMPLICATIONS: (3) ENTERIC

The enteric complication rate post-pancreatic transplantation has been quoted as up to 19%, including, small bowel obstruction, colitis, fistula formation and enteric leak.<sup>16</sup>

#### Enteric leak

Enteric leak occurs in up to 3% and is usually from the anastomotic sites and can result in severe intra-abdominal infection (Figure 17).<sup>2,7</sup> Sepsis is a particular issue in enteric-drained grafts due to intraperitoneal leak of enteric contents with an associated increased rate of graft loss.<sup>14</sup> CT with oral contrast or fluoroscopy can identify the site of leak. Leaks may settle with conservative management by drainage but surgery is indicated in peritonitis or graft dysfunction. Delayed leaks, often presenting months or years after transplantation, may be a feature of post-transplant lymphoproliferative disorder (PTLD), or donor duodenal necrosis from severe vascular rejection.<sup>15,17</sup>

#### Bleeding

Bleeding may be gastrointestinal, vesical or intra-abdominal. Gastrointestinal bleeding in the early stage is most often related to the enteric or duodenal anastomoses (Figure 17).<sup>15</sup> Management is by surgical or endoluminal intervention.

Figure 10. Y graft pseudoaneurysm on (a) axial CT angiography (arrowed), (b) ultrasound showing the characteristic 'yin-yang sign' indicating bidirectional blood flow.

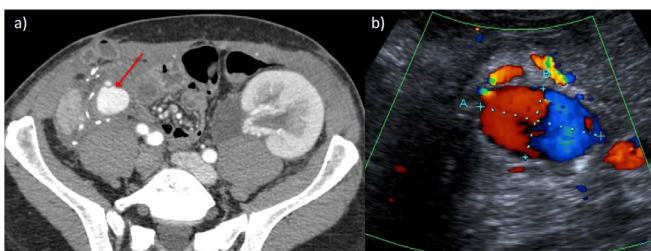


Figure 11. Thick slab coronal maximum intensity projection MRA image of a pseudoaneurysm arising from a SMA branch (arrowed).



#### Fistulae

Fistulae may form between the transplant and bowel or enterocutaneous (Figure 18). This can occur as a result of non-treated leak and a rate of up to 25% has been quoted in an SPK cohort.<sup>2</sup>

#### Small bowel obstruction

Small bowel obstruction in the context of pancreatic transplantation can be multifactorial (Figure 19) and may develop at the duodenojejunal anastomosis or be due to adhesions. The intraperitoneal placement of the graft necessitates creation of a mesenteric defect with an associated risk of internal hernia formation, which should be suspected if there are dilated, abnormally positioned bowel loops posterior to the graft resulting in a closed loop obstruction.<sup>7,14,15</sup>

#### What the transplant surgeon wants to know

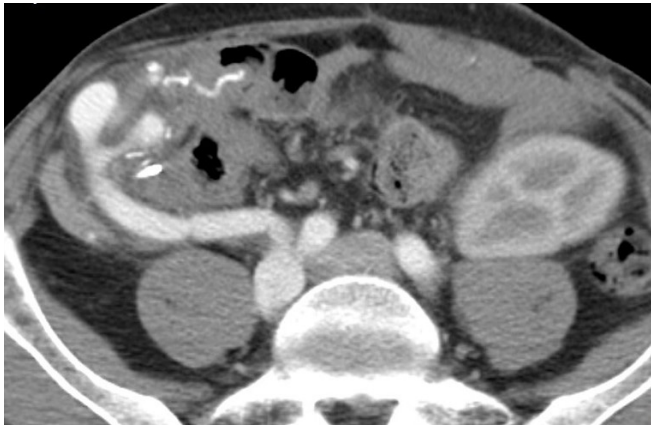
##### *Immediate post-operative period*

The immediate concern is graft perfusion; thrombosis is a major cause for non-immunological graft loss, with up to 30% early graft loss reported.<sup>2,9</sup> Serial imaging may be necessary in grafts at higher risk of thrombosis, for example, donors after cardiac death.

Figure 12. (a) Conventional angiography and (b) subsequent successful coil embolisation of a Y graft pseudoaneurysm.



Figure 13. Arteriovenous fistula (AVF) on an axial arterial phase axial CT image.



Ultrasound is often the first investigation in the immediate post-operative period at our institution. The operator should demonstrate transplant perfusion and vascular anatomy; the Y arterial graft (low resistance, forward diastolic and continuous flow), portal/graft vein, splenic artery and vein are often visible. However, partial thromboses may be easily missed. CT or MR angiography would help clarify the diagnosis and potential therapy which may include interventional procedures such as thrombolysis or percutaneous thrombectomy.<sup>10,12</sup>

#### Later post-operative period

Subsequently, concern shifts towards enteric leak and pancreatitis; the patient can present with ongoing ileus or persistent pain and raised inflammatory markers. Imaging plays a critical role in establishing the underlying cause; to differentiate between pancreatitis, necrosis from missed thrombosis, and enteric leak driving the sepsis. Any peri-transplant collections should be characterised including the potential for percutaneous access for drainage.

Months after transplantation, imaging may be required to help identify graft stenosis and/or potential feasibility of allograft biopsy.

Delayed bleeding, usually from arterio-enteric fistula or ruptured pseudo aneurysm, typically present in the few months post-transplant, or occasionally in failed pancreas transplants.

Figure 14. A patient with a large pseudoaneurysm with an AVF to the external iliac vein due to fungal arteritis on (a) arterial phase axial CT image, (b) conventional angiography, and (c) three-dimensional reconstruction.

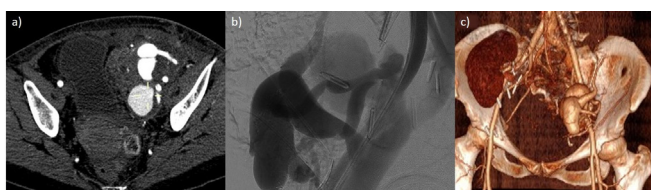
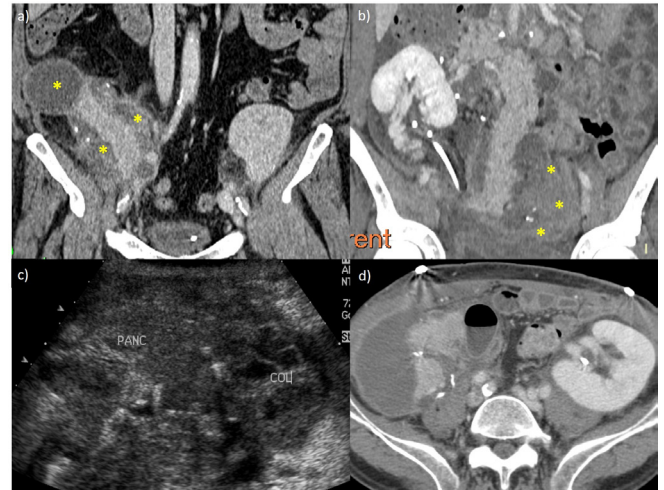


Figure 15. Various examples of peripancreatic collections: a, (b) coronal CT image showing multiple fluid density collections around the right iliac fossa graft (asterisk). (c) ultrasound showing a heterogenous collection (col) adjacent to the pancreatic transplant (panc). (d) Axial CT image demonstrating fluid around the graft.



The imaging appearances of acute and chronic rejection are non-specific with the graft appearing enlarged, oedematous with decreased enhancement.<sup>7,14,15</sup> In suspected rejection, timely communication with surgical team is essential. A caveat to note is that pancreatitis and vascular complications can give similar findings. If inconclusive, CT or MR angiography and/or ultrasound or CT-guided biopsy may be indicated.

Post-transplant lymphoproliferative disorder is a late complication occurring up to 6% of patients.<sup>17,18</sup> PTLD may present with graft enlargement. Focal lesions may occur in the pancreatic graft (10%) with adjacent lymphadenopathy and focal lesions in the liver (up to 40%), spleen and bowel (Figure 20). PTLD more commonly presents with widespread disease compared to renal and liver transplants.<sup>17,18</sup> Management entails careful modification of immunosuppressant therapy.

#### SUMMARY AND CONCLUSION

For timely assessment and management of pancreatic transplant patients, it is essential that radiologists appreciate the relevant arterial, venous and exocrine anatomy. This includes an

Figure 16. a) axial and b) coronal contrast-enhanced CT images showing a diffusely oedematous right iliac fossa pancreatic graft with surrounding free fluid in keeping with pancreatitis.

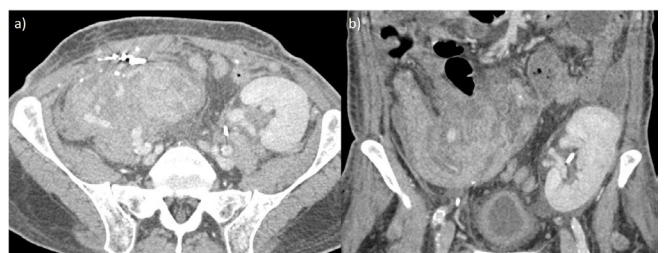
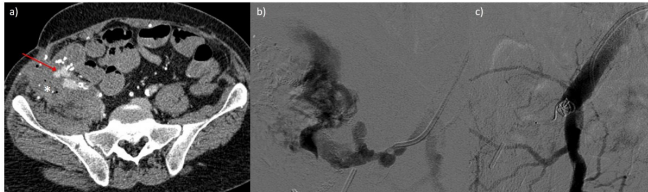


Figure 17. (a) In addition to a leak [seen as peripancreatic fluid with gas locules (asterisk)], there is also active bleeding from the graft-bowel anastomosis as demonstrated on axial CT (arrowed) and b) conventional angiography where active contrast extravasation is seen from the external iliac artery into the pancreatic graft and bowel. (c) Subsequent successful coil embolisation of the bleeding point.



understanding of the common variations in surgical technique. There is a huge range of potential complications, which can be broadly divided into vascular, parenchymal and enteric. Ultrasound is typically the first-line imaging modality with which the radiologist can provide vital information about the graft. Cross-sectional imaging is also commonly used in more complex cases. There is an increasing role for radiological intervention to avoid further surgical intervention.

Figure 18. (a) Axial contrast-enhanced CT and (b) CT fistulogram where contrast is injected through the skin defect demonstrating an enterocutaneous fistula which tracks towards the duodenal stump (arrowed). (c) Fistulogram demonstrates the connection to the skin surface (arrows).

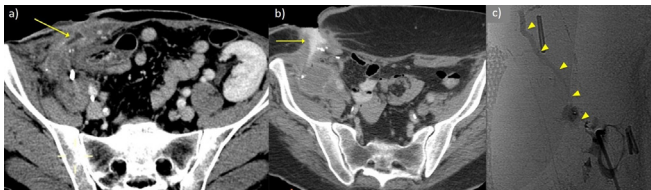


Figure 19. (a) axial and (b) coronal contrast-enhanced CT images of a stricture at the duodeno-jejunal anastomosis. There is resultant dilation of the donor duodenal stump with faecalisation of contents (arrow). Recipient jejunum (chevron); donor pancreas (P).

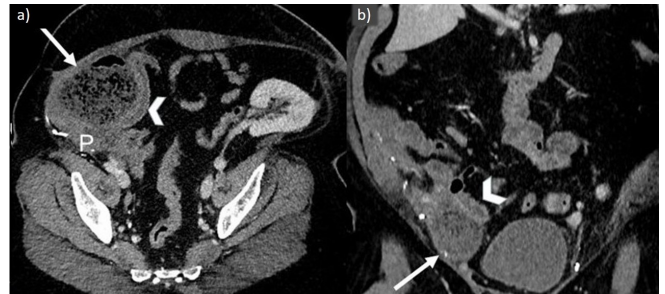
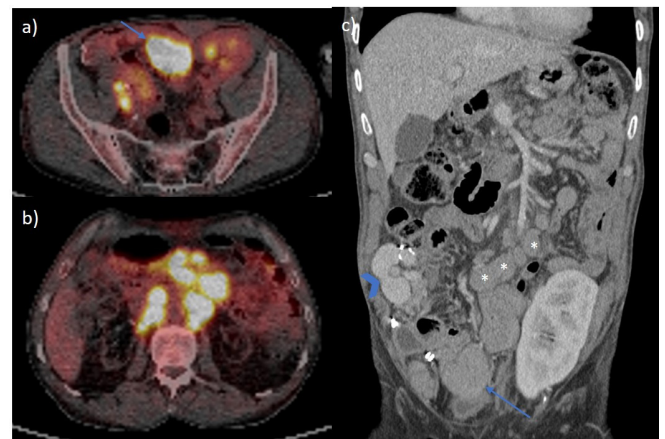


Figure 20. Fused PET/CT images demonstrate avidity in a loop of ileum (a), (arrow), histologically proven post-transplant lymphoproliferative disorder. There are multiple enlarged retroperitoneal lymph nodes, which are also markedly avid (b). (c) CT shows the ileal tumour as seen in a) (arrow) in addition to enlarged mesenteric lymph nodes (asterisk). Also note an arterio-venous fistula adjacent to the pancreatic transplant (chevron) and a left iliac fossa renal transplant.



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