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Review

Imaging of intestinal transplantation

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Intestinal transplant is considered in a small number of patients with intestinal failure or locally invasive benign abdominal tumours to improve both quality of life and survival. The complexity of the underlying diseases and postoperative findings are reflected in the imaging undertaken to support this patient group. Increasing numbers of patients are undergoing these procedures. Radiologists are increasingly likely to encounter these patients before and after surgery. This article will discuss the imaging findings that may prompt referral for transplantation assessment. It will also describe surgical anatomy and postoperative complications.

Introduction

For a small group of patients with intestinal failure or locally invasive abdominal tumours, an intestinal transplant is the favoured approach to improve both quality of life and survival. Small bowel may be transplanted in isolation or in combination with other organs, as determined by the requirements of the patient. These patients often have complex past medical and surgical histories, which means a detailed radiological assessment is required prior to transplantation. After transplantation, imaging is crucial to enable early identification and treatment of postoperative complications. Small bowel transplants are only carried out in a small number of centres worldwide. Despite this, the increasing number of patients undergoing these procedures means that radiologists outside these centres are increasingly likely to encounter these patients, both before and after surgery. This article will discuss the imaging findings that may prompt referral for transplantation assessment. It will also describe the postoperative complications, with emphasis on those that occur outside the immediate postoperative period given the relevance to those working outside small bowel transplant centres.

The current NHSBT guidelines for indications for transplant[1] are detailed in Table 1. Only a small percentage of patients with intestinal failure require referral for assessment.

Multivisceral transplant

Recently published data from the US intestinal transplant registry has demonstrated patient survival ranging from 66.1% and 40.3% at 1 and 5 years, respectively, for adult intestine–liver recipients to 1 and 5 year survival rates of 82.3% and 67.7% for paediatric intestine recipients.[2,3] This is balanced against risks related to long-term home parenteral nutrition and mortality related to the underlying disease process.

Assessment for small bowel transplantation involves an intensive multidisciplinary approach. In order to highlight

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Table 1
Conditions considered for intestinal transplantation.

	+ Other condition	Features to assess on imaging
Irreversible intestinal failure	Progressive intestinal failure-associated liver disease (IFALD)	Cirrhosis Portal hypertension
	Non-IFALD	Cirrhosis Portal hypertension
	Severe Sepsis	Collections Chest infection
	Endocarditis	Multiple soft-tissue or visceral infections/abscesses
	Metastatic infection	Discitis Visceral infarcts
	Limited central venous access (≤3 conventional sites in adults)	Venous thrombosis
	Poor quality of life	
Patients with indications for extensive surgery with partial or complete evisceration	Extensive desmoid disease	Extent and involvement of key vascular structures
	Extensive mesenteric arterial disease	Extent of intra- and extra-abdominal arterial vascular disease
	Localised malignancy, e.g., neuroendocrine tumour	Local extent and involvement of key vascular structures and Metastasis
Transplantation of other organs where exclusion of simultaneous intestinal transplantation would adversely affect patient survival or make transplantation impossible	Porto-mesenteric venous thrombosis preventing conventional liver transplantation	Extent of portomesenteric venous thrombosis Arterial vascular disease
	Further transplant considered likely	
Super urgent transplantation	Acute liver and intestinal failure	Features of acute liver failure
	Extensive portomesenteric venous thrombosis	Extent of portomesenteric venous thrombosis
	Acute arterial occlusion of superior mesenteric and coeliac arteries	Loss of coeliac and superior mesenteric arteries and extensive enterectomy
Re-transplant	Vascular thrombosis	
	Chronic rejection	
	Acute exfoliative rejection	
	CMV enteritis requiring explantation	

the important factors at preoperative imaging, it is important to have an overview of the surgery undertaken.

Surgical procedure

Approximately half of all intestinal transplants are isolated intestinal grafts.[4] Part of the donor colon is now often included, as the ileo-caecal valve slows bowel transit and improves fluid balance. There are a wide variety of surgical techniques: the liver, pancreas, kidney, stomach, duodenum, colon, and abdominal wall/fascia may all be included, in addition to the small bowel. A detailed assessment of organ function is required prior to transplantation. As well as organ failure, certain imaging findings can influence the choice of graft, for example, if there is portomesenteric venous thrombosis, a liver and small bowel containing graft will be required to address the consequences of portal hypertension and to provide portal venous inflow to the liver.

Intestinal anastomosis

In essence, the proximal anastomosis is performed between the distal end of the recipient's remaining bowel (i.e., jejunum, duodenum, stomach, or oesophagus) and the proximal portion of the donor bowel, which can be stomach, duodenum, or jejunum. This can be an end-to-side or side-to-side anastomosis. At our institution the pancreaticoduodenal complex is included *en bloc* in all small bowel transplants as it is thought to reduce vascular complications. In this case, the donor duodenum will be blind ending.[5,6] The distal end of the transplanted bowel is brought out to the surface at an ileostomy or colostomy. This allows monitoring of the graft with endoscopy and biopsies, which are particularly important in the diagnosis of acute rejection.[7] The distal transplanted bowel can also be anastomosed to the recipient distal colon, depending on the length *in situ*, with an upstream ileostomy to allow access to the graft for endoscopy.

In a multivisceral graft where the liver, pancreas, stomach, and small bowel are grafted, biliary and pancreatic drainage remain in continuity with the bowel. If the recipient liver and pancreas remain *in situ*, pancreatic and biliary drainage will be through recipient duodenum anastomosed to the graft jejunum or duodenum. Less commonly a graft roux loop may be formed to allow biliary drainage from the native liver into the donor small bowel if the native stomach, duodenum, and pancreas are excised.

Vascular anastomosis

The donor superior mesenteric artery (SMA) and coeliac artery are resected at their origin from the aorta with or without a cuff of aortic tissue. Intraoperative endovascular occlusion of the recipient coeliac, SMA and IMA can be used to reduce blood loss during recipient organ resection.[8] An

end-to-side arterial anastomosis is often performed between the donor coeliac artery and SMA and recipient aorta, inferior to the native SMA. Alternatively the donor SMA and coeliac artery can be anastomosed to the recipient aorta via a conduit, often the donor aorta (Fig 1).

The portal venous anastomosis varies according to the organs included with the graft. Direct end-to-end or end-to-side anastomosis is performed between the donor and recipient portal vein or between the donor SMV and native SMV. Alternatively, the donor portal vein may be anastomosed to the recipient IVC (Fig 2).

In *en bloc* liver and intestinal grafts, there is no portal venous anastomosis. Instead the liver is anastomosed to the systemic venous system via a caval anastomosis (often a cava-cavaplasty).

Preoperative imaging

The purpose of preoperative imaging assessment for intestinal transplantation is to establish whether there is a contraindication to surgery (Table 2) and to assist the surgeon in operative planning. The latter involves the selection of the appropriate type of graft, and intestinal and vascular anastomoses. It can also highlight the need for additional procedures prior to transplantation, such as refashioning the systemic venous system to allow adequate intravenous access peri-operatively.

Computed tomography (CT) is the most frequently used imaging method for transplant assessment. In general, an arterial phase of the abdomen is acquired, in addition to a portal venous phase acquisition of the chest, abdomen, and pelvis. Given the complexity of these patients, a template reporting system is used detailing the following: (1) hollow viscera, (2) solid viscera, (3) arteries, (4) systemic veins, (5) portomesenteric system, (6) abdominal compartment volume and abdominal wall, and (7) extra-abdominal factors.

Figure 1 Volume-rendered image demonstrating postoperative arterial anatomy in a multivisceral transplant recipient. A donor aortic conduit (arrow) with coeliac and SMA pedicles (dotted arrows) is anastomosed to recipient aorta.

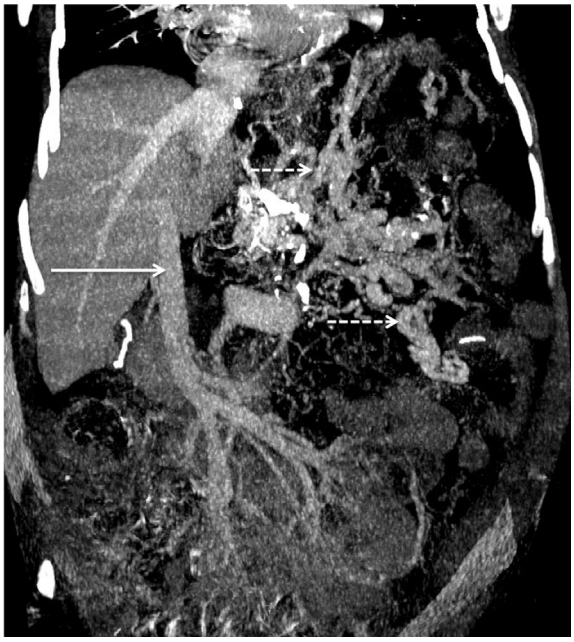

Figure 2 Venous anatomy. A portal phase coronal reformatted CT image demonstrates complex venous anatomy in a multivisceral transplant recipient with a history of portomesenteric vein thrombosis. The donor block is in continuity as such the donor bowel is drained via the donor SMV and portal vein to the donor liver (arrow). Native stomach and proximal jejunum remain *in situ* with venous drainage through pre-existing mesenteric–systemic collaterals (dotted arrows).

Hollow viscera

The entire gastrointestinal tract is reviewed. The native stomach may need to be removed if there is functional impairment (which may be suggested by CT, but confirmed using scintigraphy). The length and state of any remaining small/large bowel is determined and plans made to salvage as much viable intestine as possible. If transplantation is being considered because of a locally invasive tumour (often desmoid), the boundaries of the tumour should be documented, so that the entire tumour can be removed with clear margins.[9] This may entail resection of several abdominal organs. Assessment of these tumours is often possible using CT alone.[10] Magnetic resonance imaging (MRI) can be used if, as may be the case, the patient has little intra-abdominal fat (Fig 3).

Solid viscera

Evaluation of the native solid viscera is important to identify the appropriate organs to include in the graft. Signs of cirrhosis or portal hypertension should be sought, so that a liver-containing graft can be used if required. If there has been previous extensive enterectomy, then portal hypertension may be minimal even if the liver is frankly

Table 2
Contraindications to transplantation.

Contraindications	
Absolute	Metastatic malignant disease
	Systemic disease with poor prognosis
	Progressive impairment with severe neurological disease
Relative	Sepsis: severe systemic or active generalised infection
	Insufficient venous access
	Ventilation requirement
	Permanent stable impairment from neurological condition
	<5 years life expectancy from systemic disease
	Neoplastic disease with uncertain prognosis
	Psychiatric disease that is unlikely to respond to treatment and limit adherence
	Patients unlikely to comply with postoperative treatment
	≥60 years

cirrhotic. Where cirrhosis is present, the liver should be imaged to detect hepatocellular carcinoma. Atrophy of the kidneys or pancreas may indicate the need to include these organs in the graft, but functional assessment of these organs is more important in making this decision. Signs of unexpected metastatic disease should be sought, an absolute contraindication to transplantation that can be detected with imaging.

Arteries

In order to cross clamp the aorta, and fashion arterial anastomoses, sites of atherosclerosis should be defined: this can be assessed with CT. Arterial variants must be identified, again arterial phase CT is the investigation of choice. In patients with intestinal failure secondary to mesenteric arterial disease, there may be many unusual collateral pathways supplying the remaining vasculature, which should be highlighted to the surgical team.

Systemic veins

To enable safe transplantation, the patient must have suitable sites for intravenous access (to enable the delivery of drugs, fluids, parenteral nutrition, and blood products). Patients referred for intestinal transplantation will often be dependent on parenteral nutrition and may have had multiple venous line thromboses (in fact this may the reason for referral). For safe transplantation, a minimum of one venous access point above and one below the diaphragm is required. In view of this, the internal jugular, subclavian, and femoral veins are reviewed at portal phase CT and ultrasound (US). MRI venography is used for problem-solving. If the patient has already lost venous access at these sites, a transplant may still be carried out after surgery to restore access, for example, with refashioning of the superior vena cava.

Portomesenteric system

Patency of the portomesenteric venous system should be evaluated to define potential sites for anastomoses of a small bowel graft and to ensure splenic drainage and reduce risks of segmental portal hypertension. If diffuse portomesenteric thrombosis and cirrhosis are the indication for liver small bowel transplant then looking for sites of possible porto-caval shunts may allow an isolated liver transplant to be undertaken.

Abdominal compartment volume and abdominal wall

The abdominal compartment volume needs to be sufficient to enable closure without causing compartment syndrome. This can be formally quantified using CT.[11] In patients who have undergone several abdominal operations, there is likely to be scarring and muscular atrophy or retraction in the anterior abdominal wall (Fig 4). Highlighting a poor-quality anterior abdominal wall or a lack of volume preoperatively allows the surgeon to plan

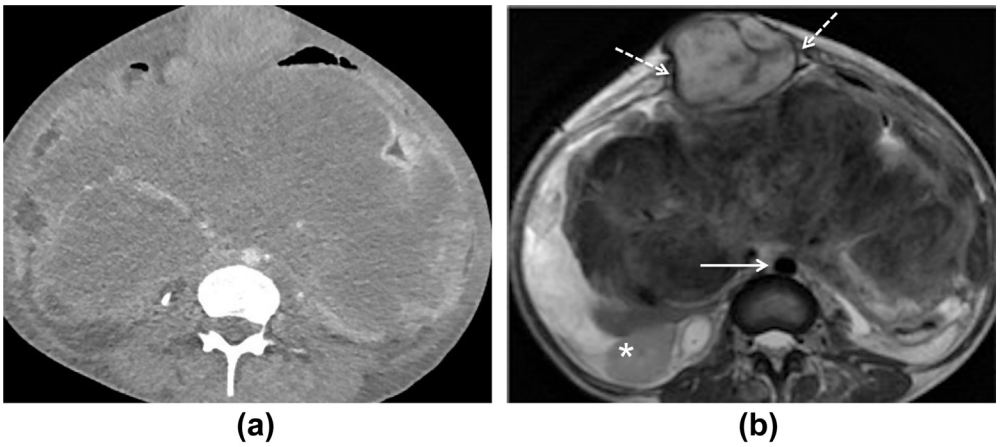

Figure 3 A 35-year-old patient with a history of familial adenomatous polyposis (FAP) and a desmoid tumour. (a) An axial CT image demonstrates the desmoid tumour involving the majority of the small bowel mesentery. (b) The extent of involvement of the abdominal wall (dotted arrows) and relation to retroperitoneal structures, e.g., the aorta (solid arrow) and right kidney (asterisk) more conspicuous at MRI.

Figure 4 A 52-year-old patient with a history of cirrhosis, pancreatitis, and portomesenteric vein thrombosis who had undergone several bowel resections. An axial CT image in portal phase demonstrates a short segment of jejunum remaining *in situ* (arrow). With only a short remnant of bowel, the abdominal cavity is markedly reduced in volume (line). The majority of the cavity visualised on the image is comprised of retroperitoneal structures.

additional measures during closure, such as the use of synthetic or porcine material, muscle splitting procedures or transplantation of donor abdominal wall or fascia.

Extra-abdominal

Given the multi-organ effects of intestinal failure (IF) and any underlying cause, the entire patient needs to be assessed for features that might impact on whether transplant is appropriate and if so, the surgical approach. Bone density is often reduced in patients with IF, and identification and treatment of osteoporosis is important to prevent fractures and associated morbidity. DEXA (dual-energy X-ray absorptiometry) can be used to assess bone density and yearly assessment is recommended for those with IF.[12] Sarcopenia as defined by grip strength and bio-impedance measurements of skeletal muscle mass has been shown to be closely associated with survival following liver transplant.[13]

Postoperative imaging

Given the complexity of the surgery, together with often chronic underlying disease processes, there are a number of complications that can arise. Ultrasound imaging on the first postoperative day is performed on those with and without hepatic grafts to identify portal venous flow. The yield of a routine standard postoperative CT is low and is increasingly only performed when complications are clinically apparent.

Normal postoperative appearances

In the early postoperative period, the bowel can appear oedematous and thick walled due to reperfusion injury, surgical handling, and loss of lymphatics and innervation. Mesenteric lymph nodes may also be enlarged due to reactive changes from ischaemia and loss of normal lymphatic drainage[4] (Fig 5); however, imaging appearances

Figure 5 Axial CT image of a recipient of a small bowel and pancreas graft demonstrating small bowel with minimal mural thickening.

of the small bowel and mesentery can return to those of native small bowel within days.

Postoperative complications

Infection

Due to immunosuppression, sepsis is the commonest complication encountered. Rejection and haematological complications can also manifest with infection, due to disruption of the mucosa and pathogen translocation. Within the first month, bacterial infections are common. It is important to evaluate common sites, such as vascular lines, catheters, and the chest.[4,14] Viral and fungal infections increase in incidence after the first postoperative month, with reported rates of infection ranging between 46–57% during the first 30 days.[15,16]

Features of typical and atypical infections can be identified at CT chest and guide further management or investigation with bronchoscopy. Abdominal CT is often performed to identify occult collections with a view to drainage. Rim enhancement and peritoneal thickening may be subtle or not visualised due to immunosuppression.[9] Not all collections are infected: seromas and haematomas are common in the early postoperative period. Chyle collections may also occur due to lymphatic disruption and may be characterised at CT with fat–fluid levels (Fig 6).

Infective enteritis can also occur in the early and late postoperative period. This is often viral in origin, such as adenovirus, Epstein–Barr virus (EBV), and cytomegalovirus, but bacterial and parasitic enteritis can also occur.[17]

Acute rejection

The diagnosis of acute cellular rejection is based on clinical evidence of graft dysfunction and histology obtained from enteric mucosal biopsies.[18] The incidence of acute cellular rejection related to small bowel transplant is higher than that associated with other solid-organ grafts. Approximately 50% of patients with intestinal transplants experience acute cellular rejection, this can occur as single or repeated episodes.[19,20]

Figure 6 Axial CT image demonstrating a chylous collection (long arrow) with layering low-attenuation fat content (short arrows).

Figure 8 Axial CT image demonstrating pneumatosis (arrow) and mesenteric venous gas (dotted arrow) secondary to acute cellular rejection; however, this patient went on to undergo enterectomy and re-graft.

CT features are non-specific and of enteritis. Appearances may mimic infection with thickened hyperenhancing bowel loops. Mesenteric oedema and ascites are often present. This has to be interpreted in the context of the clinical presentation such that sepsis is not overlooked (Fig 7). Studies and case reports of nuclear medicine and MRI techniques in assisting diagnosis of rejection have been published; however, the diagnosis is made histologically on endoscopic biopsies via the stoma.[7] Vascular injury from acute rejection can lead to thrombosis and graft ischaemia and necrosis, and is a leading cause of graft loss (Fig 8).

Chronic rejection

Chronic rejection is uncommon. This results in graft arterial myo-intimal hyperplasia causing mural ischaemia and fibrosis. Diagnosis, again, is based upon clinical symptoms and confirmed at histology.[18] Imaging plays a limited role in evaluating chronic rejection; however, this may be demonstrated as stricturing (Fig 9) with diagnosis made at full-thickness biopsy or resection.[21,22]

Vascular complications

Arterial or venous thrombosis is a cause of early morbidity with small bowel transplant recipients and occurs in 15%.[23]

Arterial complications

Arterial complications such as thrombosis, pseudoaneurysm formation, and stenosis are uncommon at 3–4%.[5,24] Arterial thrombosis is most common within the first 3 months following transplantation. There are many risk factors including the recipient's underlying prothrombotic state, mismatch between the diameters of the donor and recipient arteries, vessel position, prolonged cold ischaemic time, acute rejection, and sepsis.[23] Thrombosis presenting after the initial recovery is seen secondary

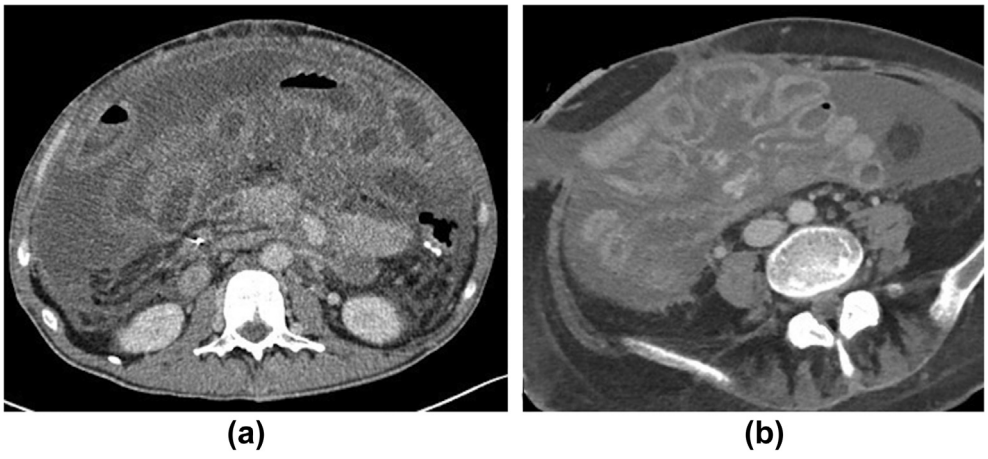

Figure 7 Axial CT images of two recipients of multivisceral transplant grafts presenting with clinical and imaging features of enteritis. Both images demonstrate marked mural thickening of the small bowel with additional mesenteric oedema and free fluid; however, this needs to be interpreted together with clinical and endoscopic findings. Figure (a) demonstrates enteritis due to norovirus and figure (b) due to acute cellular rejection.

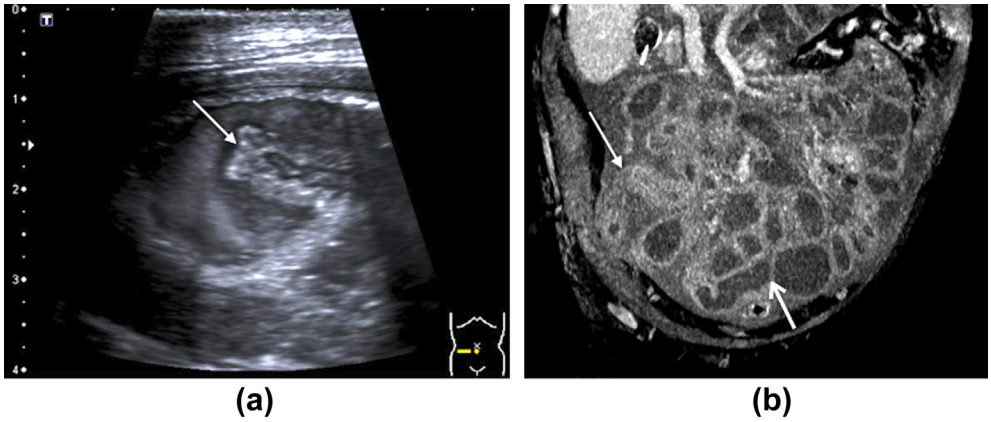

Figure 9 US and coronal reformatted CT images of a multivisceral transplant recipient 8 months following surgery with a history of abdominal pain and high stoma output. (a) US imaging demonstrates a thick-walled loop of distal ileum (arrow) with loss of peristalsis and increase in mural echogenicity. (b) CT demonstrates a distal ileal stricture (long arrow) corresponding to the findings at US and proximal relatively dilated small bowel (short arrow). The patient underwent a distal small bowel resection with pathology demonstrating features of chronic and concurrent acute rejection.

to infection and chronic rejection. Thrombus is most commonly seen in the distal aortic conduit at sites of turbulent flow; however, occlusive thrombus of branch vasculature is rare (Fig 10).

Arterial stenosis is uncommon in small bowel transplants, but can be divided into anastomotic and non-anastomotic sites. Non-anastomotic stenosis may indicate chronic rejection.[23]

Both thrombosis and stenosis may be identified at US if the transplanted liver vasculature is involved or within the small bowel main vasculature, if there is local expertise in small bowel US. CT will demonstrate a filling defect, occluded or narrow section of vessel, with a high sensitivity (100%) and specificity (87%).[25] Conventional angiography can be required to demonstrate subtle stenoses and allows concurrent intervention.

Pseudo-aneurysms may be suspected in cases of bleeding or found incidentally on CT for other indications. Infection and ischaemia have been proposed as potential causes. These may be related to the arterial conduit (Fig 11) or more commonly the hepatic component of the graft.

Venous thrombosis

Venous thrombosis is more common than arterial thrombosis. Doppler US may be used in selected patients. US and Doppler appearances are similar to complications in other viscera transplants vessels. No arterial flow may indicate SMV thrombosis and absent diastolic flow or slow arterial upstroke, dampened systolic peak, or "tardus parvus" may indicate "impending thrombosis"[26] within the SMV.

If venous compromise is suspected, most centres will perform contrast-enhanced CT. The radiologist should be aware of the venous drainage of the graft as this may involve graft portal and graft porto-systemic components. The recipient bowel may also be draining through collaterals. Thrombus should be sought at all of these sites.

Gastrointestinal complications

Anastomotic leaks

Anastomotic leaks are uncommon and present in the early postoperative period. They can be identified on

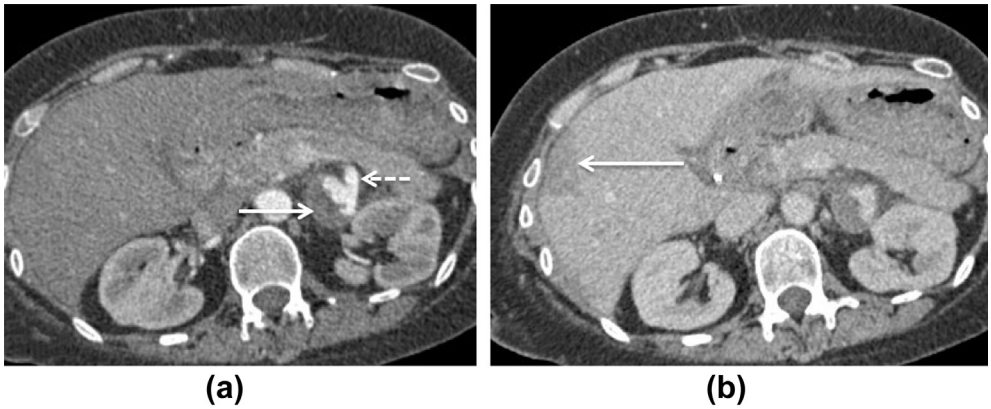

Figure 10 Axial images of the abdomen in a multivisceral transplant recipient. (a) At arterial phase, thrombus is evident in the graft aortic conduit (arrow), the coeliac artery remains patent (dotted arrow). (b) Portal phase axial image demonstrates a peripheral hepatic infarct (long arrow).

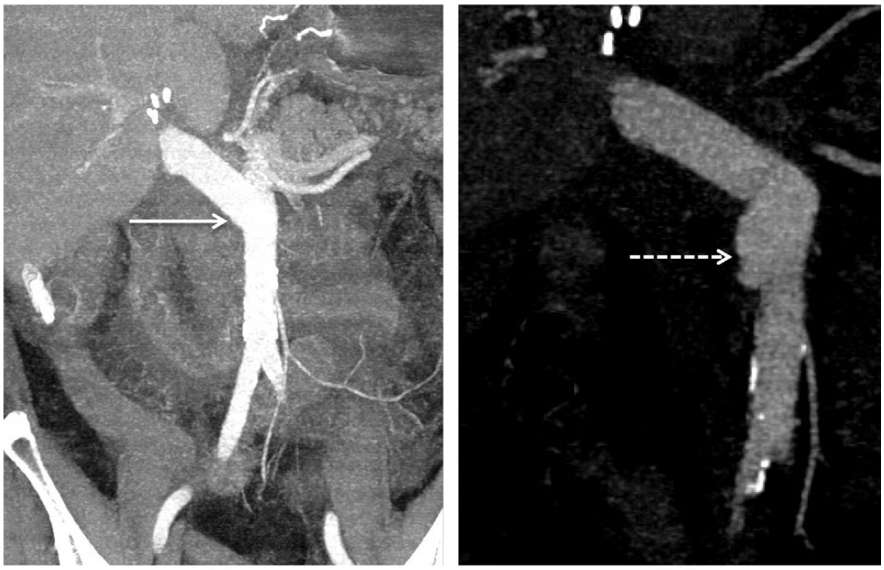

Figure 11 Coronal reformatted CT images of an aortic conduit in a multivisceral transplant recipient. At baseline imaging postoperatively, the conduit has a smooth contour (arrow). One year later the patient presented with sepsis, imaging demonstrates an aneurysm (dotted arrow) related to the aortic conduit/native aortic anastomosis due to fungal sepsis.

fluoroscopic studies, but in most centres CT with an oral water-based contrast medium is performed.[27]

Gastric emptying

Delayed gastric emptying can occur in the transplanted stomach and a pyloroplasty should be performed at the time of surgery. If delayed gastric emptying is suspected, scintingraphic studies can assist in confirming the diagnosis.[5]

Graft small bowel and colon

Bowel dysmotility is common within the first few months following transplantation presenting as both hypo- or hypermotility.[28] This needs to be distinguished from mechanical causes of bowel dysfunction, such as adhesions or strictures. Focal strictures are uncommon and may present at anastomoses or due to segments of ischaemia or chronic rejection. Fluoroscopic, CT, or MRI enterography can all be considered.

Haematological

Post-transplantation lymphoproliferative disorder (PTLD)

In general PTLD is a result of EBV viral induced proliferation of recipient B cells. Small bowel transplant and multivisceral transplant recipients (11–33%) are more commonly affected than recipients of other solid-organ transplants due to the extensive volume of donor lymphoid tissue combined with significant immunosuppression. PTLD may involve bowel, solid organ, or lymph nodes within donor or recipient organs. It can be at a single site or multifocal. It is commonly identified or suspected on CT appearances in patients with raised EBV titres or presenting with clinical features related to PTLD. Suggestive features include mural thickening with dilatation of the small bowel, low attenuation lesions within solid organs and enlarging lymph nodes. Lung involvement can also occur.[4,29]

Imaging can aid diagnosis by identifying potential sites for biopsy and histological confirmation. Combined positron-emission tomography (PET)/CT is helpful both diagnostically and also as a way of tracking post-treatment progression. Mimics are common and include atypical infection. As with sepsis, rapid progression of findings can occur. Histological confirmation should therefore be obtained rapidly such that prompt treatment with reduction in immunosuppression and/or rituximab can be initiated (Fig 12).

Graft versus host disease (GvHD)

GvHD is uncommon (up to 9%), but is associated with high mortality. The condition is often diagnosed clinically, particularly based on skin appearances and gut mucosal abnormalities.[30] CT is non-specific and findings include bowel wall thickening, mucosal hyper-enhancement, and vessel engorgement; however, these are difficult to distinguish from other aetiologies related to enterocolitis.[31]

Malignancy

As well as PTLD, recurrence of previous tumours (benign and malignant) can also occur post-transplantation. This includes desmoids, which recur in 20–68% within the first 1.5–5 years post-resection.[10] There is an increased incidence of de-novo malignancy in the transplant population due to immunosuppression and other underlying risk factors, such as viral infection and concurrent disease processes. These findings may be subtle and be found incidentally (Fig 13).

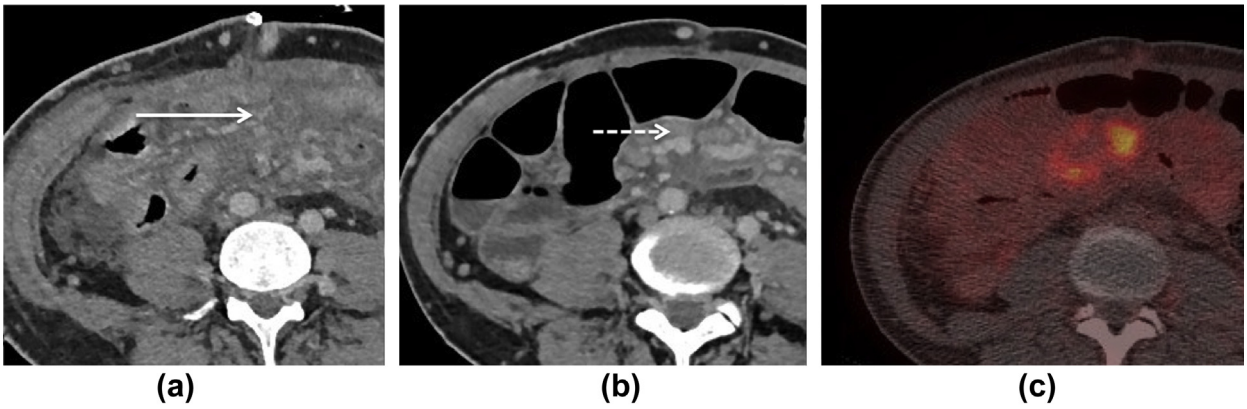

Figure 12 (a,b) Axial CT images demonstrating subcentimetre lymph nodes (arrow) in the small bowel mesentery 6 months following intestinal transplantation. Three weeks later these were seen to increase in size (dotted arrow) and are seen to be 2-[^{18}F]-fluoro-2-deoxy-D-glucose (FDG) avid at PET-CT (c). The patient was EBV positive. Subsequent biopsy of FDG-avid axillary nodes demonstrated post-transplant lymphoproliferative disease.

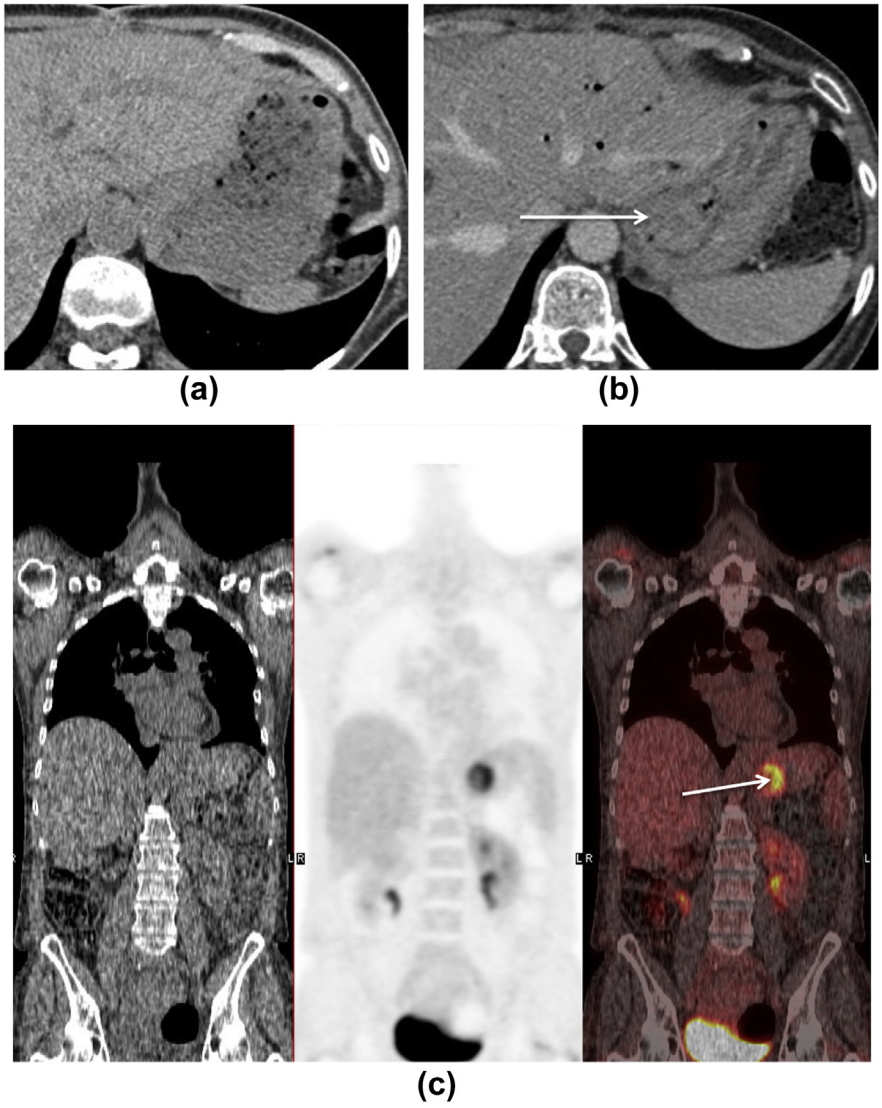

Figure 13 Axial CT imaging in a multivisceral transplant recipient with a prior history of multiple resections for adhesions resulting in short bowel and intestinal failure. Images (a) and (b) are 6 weeks apart and demonstrate evolution of a subtle gastric lesion (arrow). (c) This was FDG avid at PET-CT (arrow). Subsequent endoscopy and biopsy demonstrated gastric adenocarcinoma.

Conclusion

Imaging of small bowel and multivisceral transplant is challenging with many facets to consider, such as underlying recipient pathology and complications due to surgery and immunosuppression. The field is evolving and with it the complexity of postoperative imaging. It is therefore important to appreciate postoperative anatomy, normal appearances, and common, as well as rarer, complications.

Conflict of interest

All authors declare they have no conflict of interest .

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References

1. Multivisceral & Composite Tissue Advisory Group on behalf of NHSBT. *Intestinal transplantation: patient selection*. 2018. POL 194/4.1 Available at: https://nhsbtdbe.blob.core.windows.net/umbraco-assets-corp/7757/pol194_4_1-intestinal-patient-selection-policypdf.pdf. [Accessed 20 August 2018].
2. Smith JM, Weaver T, Skeans MA, *et al*. OPTN/SRTR 2016 Annual data report: intestine. *Am J Transplant* 2018;**18**:254–90.
3. Pironi L, Joly F, Forbes A, *et al*. Long-term follow-up of patients on home parenteral nutrition in Europe: implications for intestinal transplantation. *Gut* 2011 Jan;**60**(1):17–25.
4. Rees MA, Amesur NB, Cruz RJ, *et al*. Imaging of intestinal and multivisceral transplantation. *RadioGraphics* 2018 Mar-Apr;**38**(2):413–32.
5. Rutter CS, Amin I, Russell NK, *et al*. Adult intestinal and multivisceral transplantation: experience from a single center in the United Kingdom. *Transplant Proc* 2016 Mar;**48**(2):468–72.
6. Mercer DF, Brady MJ, Jain G. Should the pancreas be routinely included with an intestinal graft? *Curr Transplant Rep* 2015;**2**(2):159–63.
7. Godfrey EM, Upponi SS, See TC, *et al*. A radiologist's guide to small bowel and multivisceral transplantation. *Clin Radiol* 2013 Oct;**68**(10):983–91.
8. Ceulemans LJ, Jochmans I, Monbaliu D, *et al*. Preoperative arterial embolization facilitates multivisceral transplantation for portomesenteric thrombosis. *Am J Transplant* 2015 Nov;**15**(11):2963–9.
9. Mullen JT, Delaney TF, Kobayashi WK, *et al*. Desmoid tumor: analysis of prognostic factors and outcomes in a surgical series. *Ann Surg Oncol* 2012 Dec;**19**(13):4028–35.
10. Braschi-Amirfarzan M, Keraliya AR, Krajewski KM, *et al*. Role of imaging in management of desmoid-type fibromatosis: a primer for radiologists. *RadioGraphics* 2016 May-Jun;**36**(3):767–82.
11. Gerlach UA, Pascher A. Technical advances for abdominal wall closure after intestinal and multivisceral transplantation. *Curr Opin Organ Transplant* 2012 Jun;**17**(3):258–67.
12. Pironi L, Arends J, Bozzetti F, *et al*. ESPEN guidelines on chronic intestinal failure in adults. *Clin Nutr* 2016 Apr;**35**(2):247–307.
13. Kaido T, Tamai Y, Hamaguchi Y, *et al*. Effects of pretransplant sarcopenia and sequential changes in sarcopenic parameters after living donor liver transplantation. *Nutrition* 2017 Jan;**33**:195–8.
14. Oltean M, Herlenius G, Gäbel M, *et al*. Infectious complications after multivisceral transplantation in adults. *Transplant Proc* 2006 Oct;**38**(8):2683–5.
15. Primeggia J, Matsumoto CS, Fishbein TM, *et al*. Infection among adult small bowel and multivisceral transplant recipients in the 30-day postoperative period. *Transpl Infect Dis* 2013 Oct;**15**(5):441–8.
16. Silva JT, San-Juan R, Fernandez-Caamano B, *et al*. Infectious complications following small bowel transplantation. *Am J Transplant* 2016 Mar;**16**(3):951–9.
17. Nagi S, Mangus RS, Anderson E, *et al*. Cytomegalovirus infection after intestinal/multivisceral transplantation: a single-center experience with 210 cases. *Transplantation* 2016 Feb;**100**(2):451–60.
18. Wu G, Cruz R, Cai J. Acute antibody-mediated rejection after intestinal transplantation. *World J Transplant* 2016;**6**(4):719–28.
19. Fishbein TM. Intestinal transplant. *N Engl J Med* 2009 Sep 3;**361**(10):998–1008.
20. Dunne CM, Massey DC, Woodward JM, *et al*. Diagnosis and treatment of acute cellular rejection (ACR) following intestinal transplant performed at Addenbrooke's Hospital, Cambridge, Cambridge University Hospitals. *Transplantation* 2017 Jun;**101**(6S2):S80.
21. Giovanelli M, Gupte GL, Sharif K, *et al*. Chronic rejection after combined liver and small bowel transplantation in a child with chronic intestinal pseudo-obstruction: a case report. *Transplant Proc* 2008 Jun;**40**(5):1763–7.
22. Swanson BJ, Talmon GA, Wisecarver JW, *et al*. Histologic analysis of chronic rejection in small bowel transplantation: mucosal and vascular alterations. *Transplantation* 2013 Jan 27;**95**(2):378–82.
23. Low G, Crockett AM, Leung K, *et al*. Imaging of vascular complications and their consequences following transplantation in the abdomen. *RadioGraphics* 2013 May;**33**(3):633–52.
24. Abu-Elmagd KM, Costa G, Bond GJ, *et al*. Five hundred intestinal and multivisceral transplantations at a single center: major advances with new challenges. *Ann Surg* 2009 Oct;**250**(4):567–81.
25. Kayahan Ulu EM, Coskun M, Ozbek O, *et al*. Accuracy of multidetector computed tomographic angiography for detecting hepatic artery complications after liver transplantation. *Transplant Proc* 2007 Dec;**39**(10):3239–44.
26. Nolten A, Sproat IA. Hepatic artery thrombosis after liver transplantation: temporal accuracy of diagnosis with duplex US and the syndrome of impending thrombosis. *Radiology* 1996 Feb;**198**(2):553–9.
27. Clouse JW, Kubal CA, Fridell JA, *et al*. Post transplant complications in adult recipients of intestine grafts without bowel decontamination. *J Surg Res* 2018 May;**225**:125–30.
28. Walther A, Coots A, Nathan J, *et al*. Physiology of the small intestine after resection and transplant. *Curr Opin Gastroenterol* 2013 Mar;**29**(2):153–8.
29. Wozniak LJ, Mauer TL, Venick RS, *et al*. Clinical characteristics and outcomes of PTLD following intestinal transplantation. *Clin Transplant* 2018 Aug;**32**(8):e13313.
30. Wu G, Selvaggi G, Nishida S, *et al*. Graft-versus-host disease after intestinal and multivisceral transplantation. *Transplantation* 2011 Jan 27;**91**(2):219–24.
31. Shimoni A, Rimon U, Hertz M, *et al*. CT in the clinical and prognostic evaluation of acute graft-vs-host disease of the gastrointestinal tract. *Br J Radiol* 2012 Aug;**85**:e416–23.