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REVIEW ARTICLE

Intestinal transplants: review of normal imaging appearance and complications

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ABSTRACT

Intestinal transplant (IT) is one of the least common forms of organ transplant but is increasing both in volume of cases and number of centers performing intestinal transplants, with the busiest centers in North America and Europe. IT can be performed in isolation or as part of a multivisceral transplant (MVT). Intestinal failure either in the form of short gut syndrome or functional bowel problems is the primary indication for IT. The normal post-surgical anatomy can be variable due to both recipient anatomy in regard to amount of residual bowel and status of native vasculature as well as whether the transplant is isolated or part of a multivisceral transplant. Complications of isolated IT and IT as part of an MVT include complications shared with other types of organ transplants such as infection, rejection, post-transplant lymphoproliferative disorder and graft versus host disease. Mechanical bowel complications of the graft include bowel obstruction, stricture, leak, perforation and enterocutaneous fistula. Lastly, vascular complications of both the venous and arterial anastomoses including stricture and pseudoaneurysm occur.

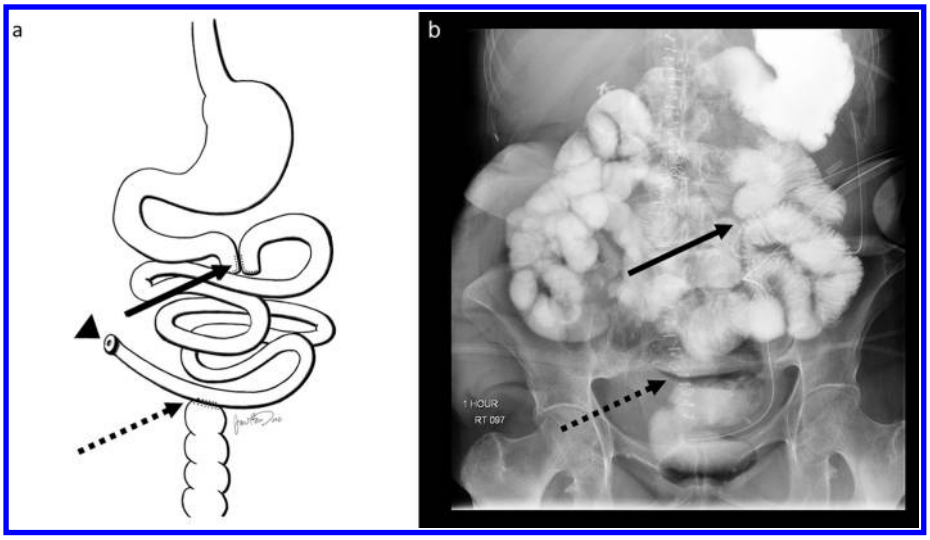
INDICATIONS

IT has become an established treatment option for patients with intestinal failure. The number of cases and centers performing IT in the United States has steadily increased from 5 cases in 1990 to 146 cases in 2016.[1] The number of patients added to the IT waiting list also has increased, from 152 in 2012 to 195 new patients in 2016, with 270 patients on the waiting list at the end of 2016.[1,2] The most common indication for isolated IT is intestinal failure, defined as an inability of the GI tract to maintain adequate nutrition and/or fluid balance. Intestinal failure may be secondary either acquired or congenital causes. Intestinal failure is further classified into short gut syndrome and functional bowel problems.[3] The most common underlying etiologies of short gut syndrome in adults are intestinal ischemia, inflammatory bowel disease, trauma and infiltrating tumors such as desmoids.[4] Most other cases of IT are seen in patients transitioning off total parenteral nutrition (TPN), which is the standard of care for patients with pre-transplant intestinal failure. Currently, more than 40,000 patients in the United States depend on TPN for survival.[5] Unfortunately, TPN is associated with a variety of common comorbidities, including catheter-associated infections, metabolic bone disease, TPN-induced cholestasis, loss of site for vascular access and catheter occlusion.[6] Patients who are TPN-dependent and subsequently require IT are also more likely to require a MVT due to end-stage liver failure, which includes the intestine and liver with or without the pancreas.[7]

NORMAL POST-SURGICAL BOWEL AND VASCULAR ANATOMY

The isolated IT involves either transplantation of the entire cadaveric small bowel, which is preferable, or a shorter segment of small bowel from a living donor. The nature of the surgery may vary dependent on what degree of stomach, small bowel and large bowel the recipient retains. Typically, there is a proximal end-to-side or side-to-side anastomosis of the proximal donor intestine to the native recipient duodenum/jejunum. For an MVT, there is often anastomosis between the donor stomach and the recipient proximal stomach. Distally, a second end-to-side anastomosis is formed between the distal segment of the donor bowel to recipient bowel, most commonly donor ileum to the sigmoid colon with an end-to-side anastomosis (Figure 1). A segment of ileum from the distal end-to-side anastomosis is extended to the abdominal wall with construction of a temporary "chimney" ileostomy which allows for less invasive access for endoscopic graft surveillance and biopsy.

Figure 1. A 62-year-old female with history of short gut syndrome secondary to multiple bowel resections, nine days after IT. Schematic illustration (a) and UGI (b) of the abdomen demonstrate the proximal anastomosis (black arrow in a and b), most commonly a side-to-side jejunojejunostomy. The distal end-to-side ileocolic anastomosis (dashed arrow in a, b) most commonly involves the sigmoid colon. Chimney ileostomy (arrowhead in a) also noted.



The ileostomy is often taken down upon stabilization of immunosuppressive therapy. IT graft surveillance after that point is typically done via colonoscopy.

Post-operative nutritional support can be achieved via different means. In our institution, if the patient has a gastrostomy tube, that is converted to a gastrojejunostomy tube preoperatively. Otherwise, a nasojejunal tube is placed for post-op feeding. We avoid placement of intra-operative feeding jejunostomy tubes due to increased risk of chronic enterocutaneous fistula.

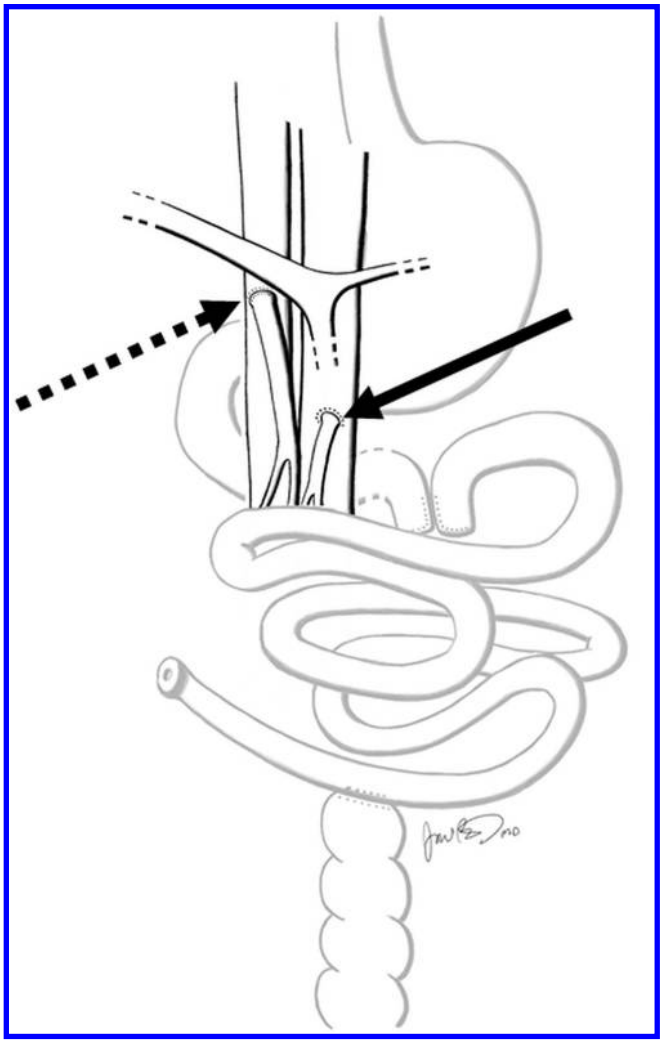
Preoperatively, multidetector CT (MDCT) with intravenous contrast of the recipient may be performed to assess the caliber and patency of the splanchnic vessels and guide the vascular anastomoses. Both arterial and venous anastomoses need to be performed (Figure 2). For isolated IT, if the recipient superior mesenteric artery (SMA) is good quality and adequate length, then a recipient SMA to donor SMA anastomosis is made by extending either of the sides with the donor carotid or iliac artery. If the recipient SMA is too short or poor quality, then a donor SMA to recipient infra-renal abdominal aorta anastomosis is made with an extension via an arterial graft. If the recipient superior mesenteric vein (SMV) is adequate length and caliber, then an anastomosis between recipient SMV to donor SMV is made with or without an extension graft, usually using donor iliac vein or jugular vein. If the recipient SMV is inadequate due to short length or narrow caliber, the venous anastomosis is made via recipient inferior vena cava (IVC) to donor SMV with an extension graft from donor iliac vein or jugular vein. This situation of mesenteric vein anastomosis directly to the IVC theoretically increases the likelihood of development of hepatic encephalopathy via creation of a portosystemic shunt, however this is quite uncommon, with only one case report documenting relapsing encephalopathy due to a combination of post-transplant metabolic disturbances, dehydration and direct mesenteric to caval shunt anatomy.[8] Other causes of encephalopathy including tacrolimus neurotoxicity, CNS infections and metabolic disturbances post-transplant account for the vast majority of encephalopathic episodes.[9]

IMAGING EVALUATION

Pre-operatively, most if not all patients will undergo MDCT of the chest, abdomen and pelvis with intravenous contrast and neutral oral contrast agent; water, to assess native arterial and venous vasculature, anatomy of the native abdominal viscera, as well as to detect occult malignancy which may preclude the patient from undergoing transplantation.[10] We do not administer a positive oral contrast agent in the event that three dimensional reconstructions are needed. Fluoroscopic evaluation with barium can assess for pre-operative enterocutaneous fistula as well as to assess the length of the residual small bowel, however this has been largely supplanted by MDCT.[11] Although MDCT has largely replaced fluoroscopy in both the pre-operative and post-operative settings, fluoroscopic upper gastrointestinal series with small bowel follow through is frequently obtained both as an overview of native bowel anatomy as well as to assess bowel motility/transit time.[12]

Post-operatively, fluoroscopic studies allow for early evaluation of graft anatomy, functional tone and motility as well as for the detection of early and late postoperative complications including bowel obstruction, perforation, entero-enteric or enterocutaneous fistulae as well as anastomotic leak or stricture. Optimally, this is performed with water soluble oral contrast in the post-operative setting given potential for anastomotic leak. Color doppler ultrasound is predominantly utilized in the postoperative setting as a tool to assess the donor and recipient vasculature, which can be performed on a portable basis and provides accurate and early assessment for elevated mesenteric and intestinal wall arterial resistive indices as well as for arterial/venous thrombosis, a potential early complication. MDCT, preferably with the use of intravenous and oral positive contrast, is the

Figure 2. Schematic illustration of an isolated IT demonstrates normal vascular anastomoses, including the donor SMA to the recipient infrarenal abdominal aorta (solid arrow) and anastomosis of the donor SMV to the recipient IVC (dashed arrow). SMA, superior mesenteric artery; SMV, superior mesenteric vein; IVC, inferior vena cava.



modality of choice for detection of complications including fluid collections, abscesses, fistulae, as well as enteric and vascular anastomotic complications. Routine CT evaluation is performed with both intravenous and water soluble positive oral contrast. We utilize a weight based dose of IV contrast varying between 100 and 150 ml of iodinated contrast. Intravenous contrast is essential in detecting vascular compromise and enhancing abnormalities such as abscess. Oral contrast is dilute iodinated contrast and is valuable in assessing for enteric leak and enteric fistula. In the early peri-operative period, oral contrast is crucial given the potential for enteric anastomotic leak. Unless vascular complications are suspected, images are acquired in a single venous phase utilizing a 70 s time delay after onset of IV contrast injection. If vascular complications are suspected, either a CT angiogram or a dual phase protocol is performed depending on the level of suspicion for an arterial or venous complication. The dual phase acquisition is performed with both an arterial phase acquisition of the upper abdomen to include the arterial anastomosis followed by a venous phase acquisition of the abdomen and pelvis obtained 70 s after onset of contrast injection to evaluate the venous anastomosis. For the CT angiogram and the dual phase acquisition, no positive oral contrast is administered; to allow for three dimensional reconstructions as needed. Tailored imaging including CT Enterography can be performed as warranted in evaluation of IT.

Abdominal MRI may also be utilized in evaluation of the IT patient; particularly in those who should not receive iodinated IV contrast due to renal insufficiency or contrast allergy. It is of greatest utility in evaluating vascular complications but MRI Enterography can evaluate for signs of infection, mechanical bowel complications such as obstruction and stricture. It may be of lesser utility in the acutely ill IT patient given relatively prolonged imaging times. We rarely utilize MRI for the evaluation of vascular anastomoses and reserve its use for patients with contraindication to iodinated contrast material. Our protocol uses a combination of both non-contrast time-of-flight imaging as well as a gadolinium enhanced three dimensional gradient based MR angiography. We utilize a Group II gadolinium agent, gadobutrol, regardless of renal function based on risk assessment of gadolinium agents in the setting of renal insufficiency as recently reviewed by the American College of Radiology and European Society of Urogenital Radiology guidelines.[13,14]

NORMAL APPEARANCE OF IT

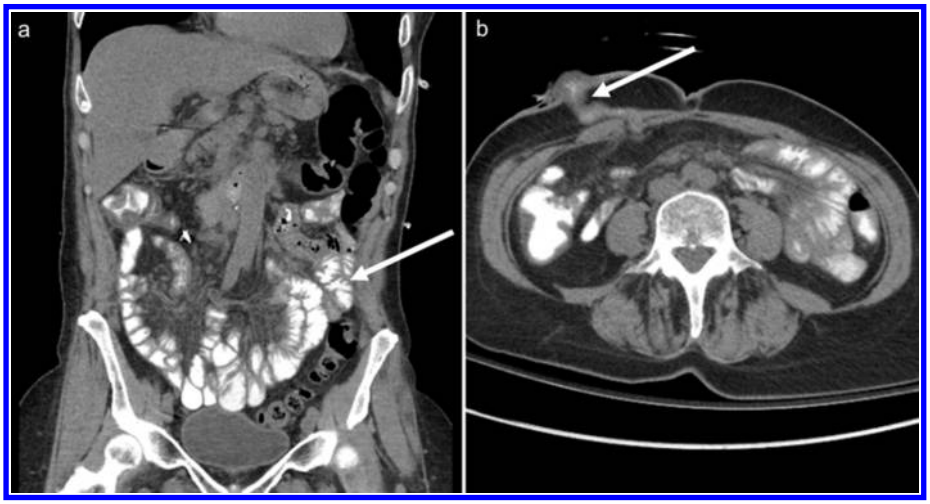
The transplanted small bowel is commonly in a central location within the abdomen. The normal transplanted bowel may appear similar to normal native bowel. However, normal postoperative imaging findings after IT overlap with pathologic processes given the inherent denervation of the transplant and diminished lymphatic drainage. Short segments of mild luminal dilatation or bowel wall/fold thickening are common, seen in approximately one third of patients in the peri-transplant period (Figure 3).[15] These findings typically persist in the first 3 months post-transplant.[15] A small amount of mesenteric oedema/ascites is also relatively common with mucosal hyperenhancement seen less commonly in only 11% of patients.[15]

COMPLICATIONS OF IT

Infection

The various forms of infection constitute the leading cause of mortality after IT. Infection is the attributable cause of mortality in up to 17.8% of all IT recipients, and in IT patients who had expired, up to 76.2% of those had documented infections.[16] Infection has also been attributed as the second most common cause of allograft loss after rejection.[17] The high level of immunosuppression as well as the high levels of intraluminal flora within the transplanted bowel predispose the transplanted bowel to a high infection risk, and almost all patients will experience an infectious episode in the first month post-transplant. The large volume of native lymphoid tissue within the transplanted bowel also requires a higher degree of immunosuppression, which in turn increase patient susceptibility to opportunistic infections and malignancy.[18]

Figure 3. A 55-year-old female 2 years after IT. Coronal (a) and axial (b) MDCT with oral contrast demonstrate a normal IT transplant with normal caliber small bowel with slight fold thickening in the jejunal loops (arrow in a). A right lower quadrant "chimney" ostomy is present (arrow in b).



When there is a clinical concern for an infectious process, MDCT with IV and positive oral contrast is our initial study of choice. This is frequently performed to exclude a process that can be intervened on such as an abscess which is readily identified on CT. Positive oral contrast is preferred to help identify enteric leaks and fistula; if present as they may be the source of an infectious process. If the patient had cannot tolerate IV contrast, we will proceed with MDCT with positive oral contrast but no IV contrast initially due to the ready availability of CT but will subsequently perform contrast enhanced MRI Enterography to assess the bowel and solid abdominal organs if clinically warranted.

Potential causes of infection include bacterial, viral, protozoan and fungal organisms. IT infection is classified into two time periods; immediate (<6 weeks) or later (>6 weeks) post-transplantation period.[19] In the immediate post-transplantation period, health care-associated infections, most commonly Gram-negative bacteria such as Escherichia coli and fungal Candida species, predominate. The most common sites include the respiratory tract, peritoneal cavity and operative wound as well as sites of catheterization. Intra-abdominal abscesses are also common (Figure 4). Abscess in the setting of IT has the typical imaging features of intra-abdominal abscess seen in other clinical settings including low attenuation/fluid center, peripheral rim enhancement and variable presence of internal gas.

In the later post-transplantation period, similar causative organisms as in the immediate period are seen along with the addition of a wide variety of viral etiologies including Cytomegalovirus (CMV), Epstein-Barr Virus (EBV), Adenovirus and others. A single center case series by Nagai et al demonstrated an incidence of CMV infection in 17% of adults and 12% of pediatric patients following IT and MVT with a median onset of infection 347 days postoperative.[20] Both EBV and Adenovirus are viral species that remain latent in lymphoid tissue and patients are

Figure 4. A 56-year-old female 1 month after IT, presenting with fever, nausea, vomiting and abdominal pain. Coronal (a) and axial (b) contrast-enhanced MDCT images demonstrate a well-defined peripherally enhancing fluid collection in the central abdomen (arrow in a and b), confirmed as an abscess.

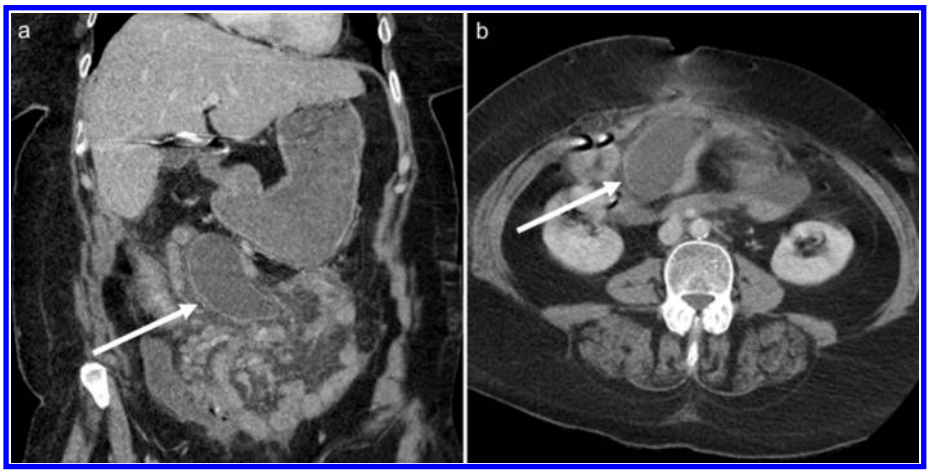
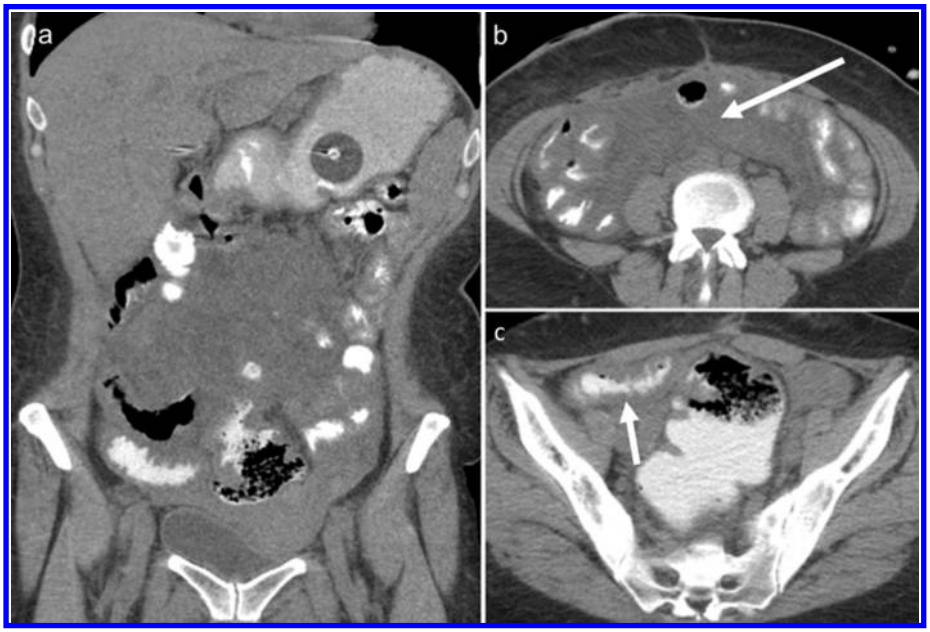


Figure 5. A 44-year-old female 2 months after IT. Coronal (a) and axial MDCT (b, c) with oral contrast demonstrate abnormal soft tissue in the mesentery (arrow in b) favored to represent a combination of conglomerate nodal tissue and ascites with small bowel thickening (arrow in c). Small bowel biopsy confirmed acute enteritis and was positive for adenovirus. MDCT, multidetector CT.



at risk of reactivation after transplantation. Adenovirus is seen most commonly in children and young adults, with a reported incidence of 20% in a single series.[21] The main clinical manifestation of Adenoviral enteritis is osmotic diarrhoea with or without associated fever. Dissemination to secondary sites including the lung, liver and pancreas is not uncommon.[22] Adenovirus involvement of other organs has a varied appearance. CT findings in the setting of an adenoviral pneumonia usually manifests as nonspecific extensive bilateral ground glass opacities with or without consolidation.[23] Hepatic involvement typically manifests as a nonspecific hepatitis, with hepatomegaly and periportal oedema, with ascites and gallbladder wall thickening possible. Pancreatic involvement usually manifests with imaging features of acute pancreatitis, which often times can be normal or present with pancreatic enlargement, oedema and peripancreatic inflammation.[24]

In the setting of an infectious enteritis, MDCT demonstrates segmental or diffuse hypo- or hyperenhancing small bowel mucosa most commonly with low density submucosal wall thickening (Figure 5).[25] Mesenteric lymphadenopathy can be seen with both bacterial and viral organisms. MDCT appearance of infectious enteritis and rejection may share similar imaging findings, and endoscopic biopsy utilizing the chimney ileostomy is often required for definitive diagnosis. Intra-abdominal ascites is more commonly seen in the setting of rejection than infection and can be a clue to the proper diagnosis, although this is not a definitive finding (Figure 6).[15] Other imaging modalities are

Figure 6. A 58-year-old male 1 week status post MVT. Coronal (a) and axial (b) MDCT demonstrates hyperenhancement of the small bowel mucosa (arrows in a) and simple-fluid attenuation ascites (arrow in b). Intra-abdominal fluid washout grew Vancomycin resistant Enterococcus faecium species. MDCT, multidetector CT; MVT, multi visceral transplant.

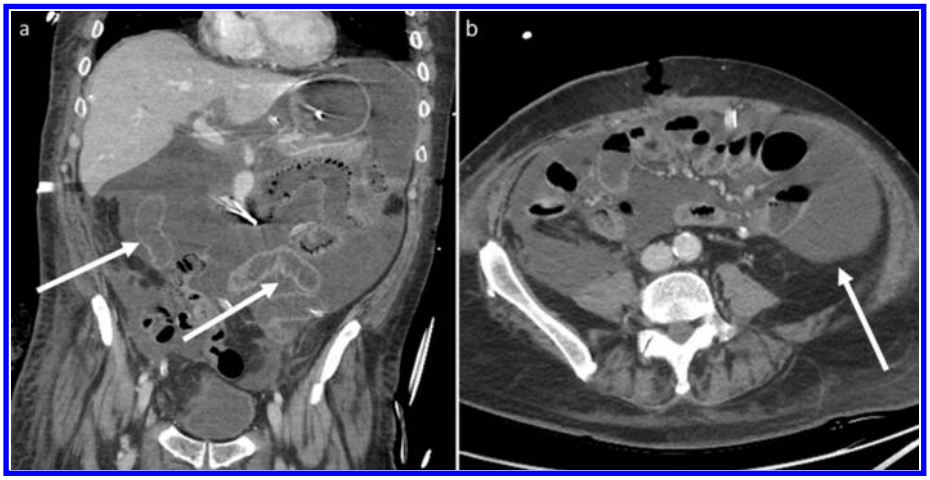
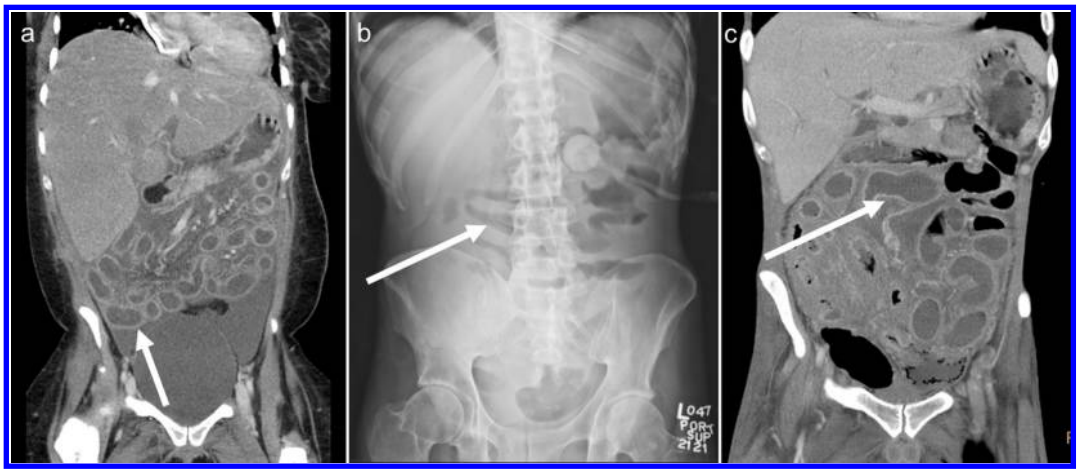


Figure 7. Two patients with acute rejection. A 28-year-old female 1 year status post MVT. Coronal MDCT (a) demonstrates mild, diffuse small bowel wall thickening and increased mucosal enhancement (arrow) with ascites consistent with rejection. A 38-year-old male 1 year status post IT with acute rejection. Supine abdominal radiograph (b) and coronal MDCT (c) demonstrate wall thickening/oedema of the walls of the small intestine (arrow in b) with loss of the normal fold pattern and mucosal hyperemia of the small intestine (arrow in C) with ascites. MDCT, multidetector CT; MVT, multivisceral transplant.



of limited utility in the diagnostic evaluation of post-transplant infection, although FDG PET-CT may be of benefit to assess for occult infection.

Rejection

The incidence of acute cellular rejection occurred in 44.8% of adult in IT recipients at 1 year and 53% at 2 years, making it the most common complication following IT, and most often seen in the first 6 months post-transplant.[2,26,27] Chronic rejection is far less common, occurring in approximately 10–15% of patients receiving an isolated IT. The incidence, however, is rising as graft survival increases. Diagnosis of acute rejection is based on a combination of clinical signs and symptoms, endoscopy and histologic findings. Routine post-transplant endoscopic surveillance via the "chimney" ileostomy is commonly performed and varies by center. Once the ileostomy is closed, typically within 3–12 months, surveillance is performed most commonly via colonoscopy. The sensitivity and specificity of routine endoscopic surveillance in detection of rejection was 50 and 90%, respectively, while in symptomatic patients, the sensitivity and specificity fell to 43 and 67%, respectively.[28] The clinical findings of acute and chronic rejection are similar and can include weight loss, diarrhoea, fever and high-volume stooling.

On imaging, the MDCT appearance of acute rejection is nonspecific. Diffuse wall thickening with mucosal hyper- or hypoenhancement in the first 90 days with ascites is suggestive but not diagnostic (Figure 7).[29] A single-center study demonstrated moderate ascites in 20 of 21 patients who had acute rejection at the time of CT.[15] There is a paucity of literature discussing the MRI findings of rejection. In our experience, MR Enterography demonstrates similar nonspecific findings of bowel wall

Figure 8. A 45-year-old female 4 months status post IT. Axial T_2 single shot fast spin echo (a) and axial contrast-enhanced fat suppressed T_1 (b) MR enterography images demonstrates areas of mild bowel wall thickening (arrow in a), mucosal enhancement (arrow in b) and moderate small bowel dilatation. Small bowel biopsy several days prior to imaging demonstrated findings consistent with acute cellular rejection.

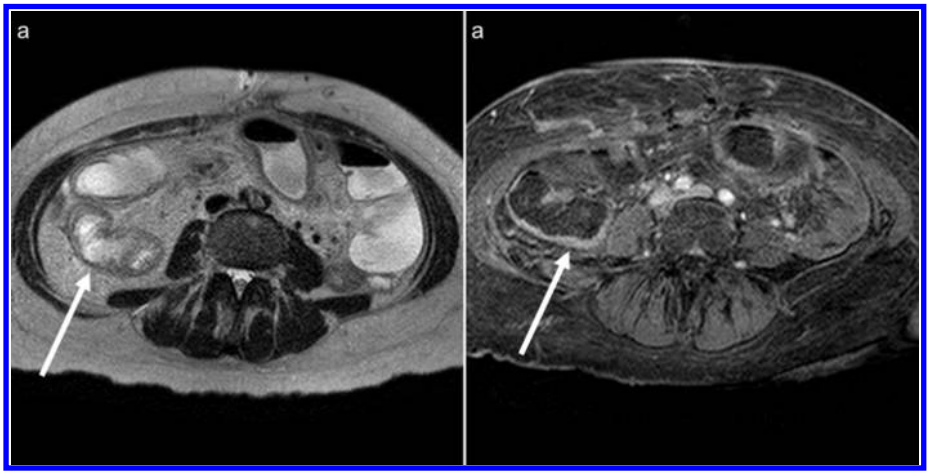
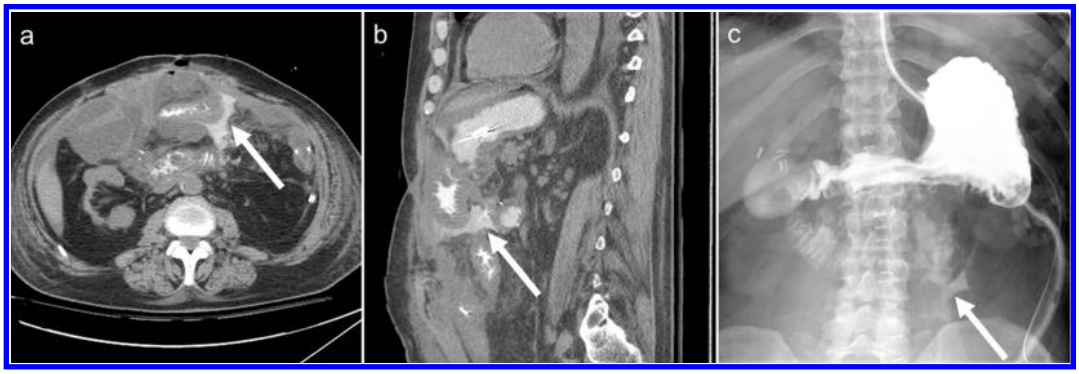


Figure 9. A 54-year-old male 8 days after IT. Axial (a), sagittal (b) MDCT with oral contrast and water soluble contrast UGI (c) demonstrate extraluminal oral contrast (arrow in a, b and c) just distal to the ligament of Treitz adjacent to the surgical anastomosis consistent with anastomotic leak. MDCT, multidetector CT.

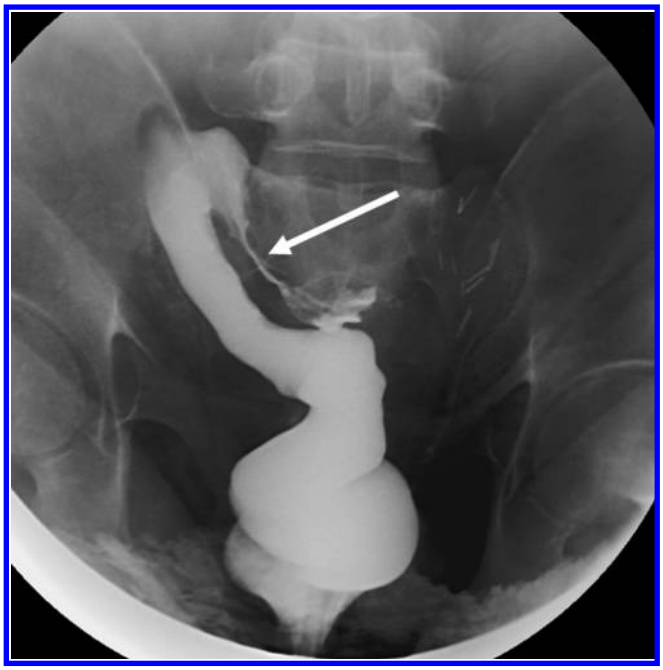


thickening and mucosal hyperenhancement on contrast-enhanced imaging (Figure 8). Fluoroscopic findings include bowel wall thickening, loss of mucosal fold pattern and hypomotility of the intestinal allograft.[29,30] In a single center study, loss of mucosal fold pattern was identified in 4 of 17 allografts, all of which demonstrated either acute or chronic rejection on histopathologic examination.[30]

Mechanical bowel complications

As with other types of bowel surgeries, postoperative mechanical complications include obstruction, anastomotic stricture, anastomotic leak, perforation and fistula. MDCT is the most sensitive and specific imaging test for the diagnosis of small bowel obstruction, while MRI may be utilized for the assessment of patients with subacute obstructive symptoms.[31] Abdominal radiographs, while commonly ordered in the emergent setting, are of limited utility for diagnosis and surgical management of IT patients as in most cases it is nearly impossible to identify the cause and site of obstruction. If small bowel obstruction is suspected, we prefer initial imaging with MDCT, optimally with IV and positive oral contrast with the goal of determining the level and cause of the obstruction. If CT is unrevealing and a low level obstruction is suspected, we will move to either MR or CT with enterography technique for further evaluation. MR is preferred if the patient cannot tolerate IV iodinated contrast. We perform fluoroscopic studies uncommonly for suspected obstruction but have found contrast enemas occasionally useful for anastomotic strictures at the enterocolic anastomosis.

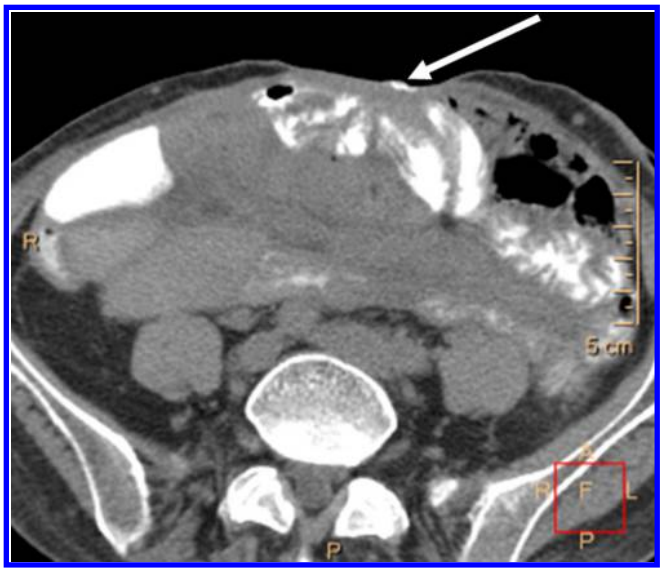
Figure 10. A 51-year-old male 1 year status post IT. Water soluble contrast enema demonstrates abrupt narrowing of the mid-to-distal sigmoid colon (arrow) consistent with an anastomotic stricture.



Imaging findings of small bowel obstruction on MDCT with IV contrast include dilated proximal bowel, greater than 3 cm in caliber, with decompressed distal small bowel and colon. Findings that are concerning for ischemia include bowel wall oedema, interloop fluid or fat stranding, diminished bowel wall enhancement and vascular engorgement.[32]

As many patients who have undergone IT have a poor nutritional status, wound and anastomotic healing is commonly impaired which can lead to anastomotic leak. If a proximal anastomotic leak is suspected, our initial study of choice is a water soluble contrast UGI with small bowel study. We reserve CT for negative fluoroscopic examinations with a high index of suspicion. If a distal anastomotic leak is suspected, we will attempt a fluoroscopic small bowel study if the length of bowel proximal to the anastomosis is relatively short as oral contrast dilution tends not to be an issue in that setting. If the fluoroscopic study is negative or the allograft length is relatively long, we will perform MDCT with intravenous and positive oral contrast to evaluate for distal anastomotic leak. Postoperative GI fluoroscopic evaluation with water-soluble contrast can demonstrate leaks with contrast extravasation near or adjacent to the proximal anastomosis (Figure 9). The more distal anastomosis is often more difficult to assess with fluoroscopy given the inherent low viscosity of the water-soluble contrast and subsequent dilution. In our experience, MDCT with oral contrast may be complementary to the fluoroscopic examination and demonstrate a leak where the fluoroscopic study failed to demonstrate a leak.

Figure 11. A 55-year-old female 1 year status post IT. CT scan with oral contrast demonstrates oral contrast on the skin surface (arrow) on the lower margin of the surgical site which was suspicious for non-visualized enterocutaneous fistula. This was subsequently confirmed on physical examination.



Anastomotic stricture is an uncommon complication but can occur at either the proximal or distal anastomosis. Stricture will present as smooth luminal narrowing on GI fluoroscopic evaluation with pre-stenotic dilatation (Figure 10).

While uncommonly encountered, enterocutaneous fistulae can be associated with a mortality rate as high as 6–33%, with electrolyte abnormalities, sepsis and malnutrition being the most common causes of death.[33] In the setting of suspected enterocutaneous fistula, we prefer to initially perform a fluoroscopic fistulogram if there is a suspected fistula on the skin surface. This involves cannulation of the cutaneous fistula opening, gentle injection of water soluble contrast agent and fluoroscopic images to visualize the tract and potential connection to adjacent bowel loops.[34] If there is no identified fistula on the abdominal wall, a fluoroscopic UGI with small bowel study is our second choice; preferably with thin barium as the contrast agent. If this examination is unrevealing we will proceed with MDCT with oral and intravenous contrast with the goal of either identifying the fistula tract or extravasated oral contrast on the skin surface. GI fluoroscopic studies can be normal if the fistula is small in size or obscured due to overlapping contrast opacified bowel loops. When evaluating for possible enterocutaneous fistula

Figure 12. A 52-year-old female 17 years after MVT. Coronal maximum intensity PET image (a) and axial fused PET-CT images of the neck (b), chest (c) and abdomen (d) demonstrates an enlarged hypermetabolic right supraclavicular lymph node (arrow in b), a focus of hypermetabolism in the interatrial septum (arrow in c) and hypermetabolic nodal tissue along the anterior gastric wall (arrow in d). Tissue sampling of the supraclavicular node revealed monomorphic PTLD. MVT, multivisceral transplant; PET, positron emission tomography; PTLD, post transplant lymphoproliferative disorder

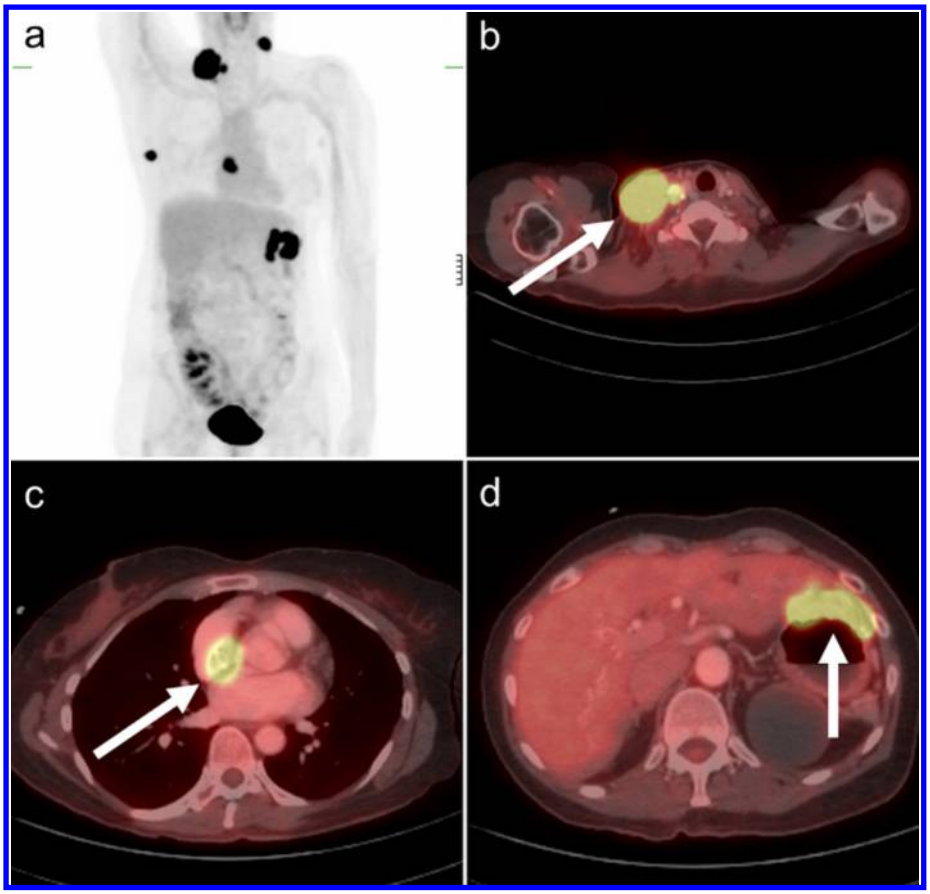
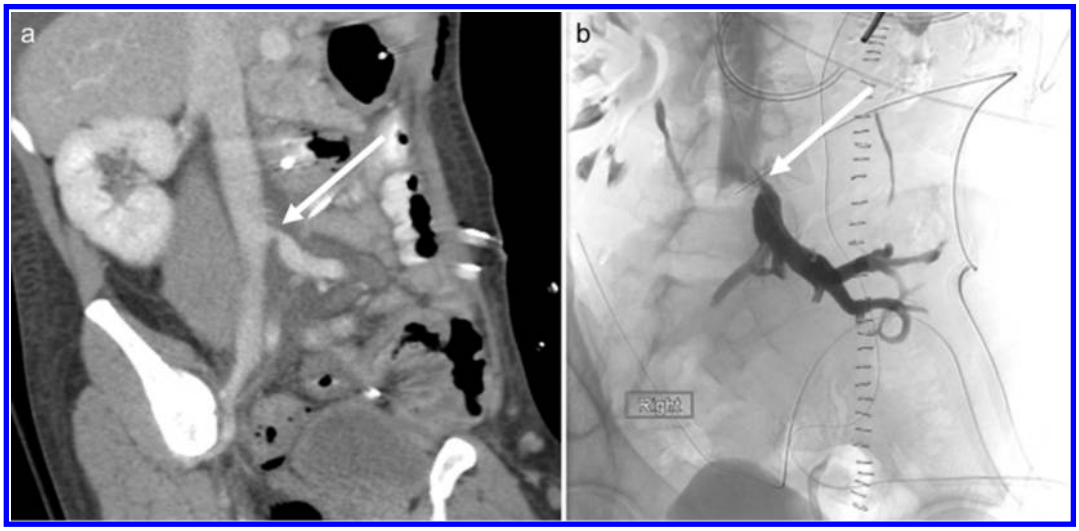
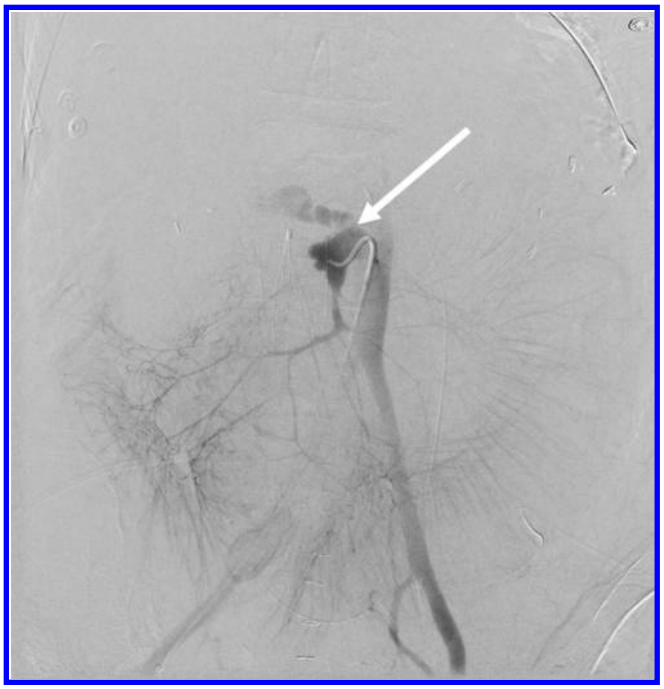


Figure 13. A 37-year-old male 2 months after IT. Curved coronal reformatted image from MDCT (a) and venogram (b) prior to balloon dilatation demonstrates stricture at the anastomosis of the donor SMV to recipient IVC (arrow). MDCT, multidetector CT; SMV, superior mesenteric vein; IVC, inferior vena cava.



with MDCT, oral contrast is optimal and may demonstrate oral contrast within loops of small bowel extending to the adjacent skin surface (Figure 11), although a direct communication may be difficult to directly visualize. Associated complications such as abscess or ileus can also be ascertained based on the MDCT findings.

Figure 14. A 61-year-old female 1 month after IT who presented emergently with severe bleeding from a previously placed abdominal drain. Superior mesenteric angiogram demonstrates a catheter within the SMA conduit with active extravasation near the anastomosis of the SMA conduit and native abdominal aorta (arrow). SMA, superior mesenteric artery.

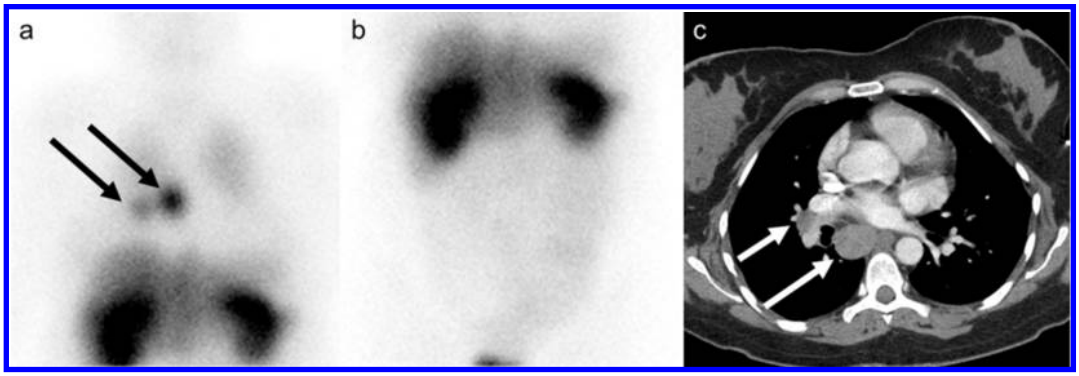


Posttransplant Lymphoproliferative Disorder

The prevalence of posttransplant lymphoproliferative disorder (PTLD) remains high, with an incidence of 7–11% in isolated IT patients and ranging from 13–33% in MVT patients.[35] The highest incidence is in the first year after transplantation when the level of immunosuppression is highest. The spectrum of disease ranges from lymphoid hyperplasia to frank neoplasm such as high-grade B cell lymphoma. The vast majority of cases result from proliferation of EBV and resultant B-lymphocyte proliferation. CMV has also been implicated in the EBV-seronegative population.[36] The anatomic distribution of PTLD is influenced by the allograft itself, and PTLD can be subdivided into nodal and extranodal varieties depending upon the primary site of disease burden.[37,38] Clinically, most patients are asymptomatic in the early stages of the disease, however, subsequently develop a constellation of nonspecific symptoms including unexplained fever, lymphadenopathy, night sweats, fatigue and allograft dysfunction which, in the setting of IT, can present as nausea, vomiting and diarrhoea.

In cases of suspected PTLD, MDCT with IV contrast is our initial preferred modality to identify apparent masses given ready availability and cost effectiveness. If PTLD of the GI tract is specifically of concern, we perform CT or MR with Enterography technique with MR Enterography preferably utilized in patients with contraindications to IV contrast. MR Enterography is preferred in the paediatric population given the lack of ionizing radiation. FDG-18 PET-CT may be utilized to look for occult disease, clarify ambiguous findings as well as follow up of treatment response. Small bowel involvement most commonly occurs in the distal jejunum and ileum, however can be seen throughout the allograft. Findings of PTLD on MDCT in the setting of IT includes diffuse wall thickening and dilatation, eccentric polypoid mass, luminal ulcerations and short-segment intussusceptions.[39] Whole-body positron emission tomography/CT can be useful in assessing for occult

Figure 15. A 35-year-old female with a history of pancreatic neuroendocrine carcinoma with liver metastases and extensive mesenteric vascular involvement who is 10 months status post IT with MVT. Anterior planar Indium-111 octreotide scan images of the chest (a) and abdomen (b) demonstrate radiotracer accumulation in recurrent malignancy in subcarinal and right hilar lymph nodes (black arrows). No metastases is present involving the allografts. Axial contrast enhanced CT scan of the chest (c) demonstrates subcarinal and right hilar adenopathy corresponding to the areas of increased uptake on octreotide scan (white arrows). MVT, multivisceral transplant.



disease, in resolving equivocal clinical or imaging findings as well as to gauge treatment response (Figure 12).[38] Imaging findings are similar to those seen in Hodgkin and non-Hodgkin Lymphomas. Both nodal and extranodal sites of disease demonstrate intense ^{18}F-FDG uptake, with the more aggressive subtypes of PTLD demonstrating significantly higher standardized uptake values (SUV) compared with the less aggressive subtypes. MRI can demonstrate T_1 hypointense and mildly T_2 hyperintense solid organ lesions with variable enhancement.[40] PTLD of the GI tract may demonstrate circumferential wall thickening, nodular masses, aneurysmal dilatation of bowel and areas of ulceration. On MR, PTLD of the GI tract may have low signal intensity on both T_1 and T_2 imaging and is relatively hypovascular on contrast enhanced MRI.[38]

Graft *vs* Host Disease

Graft versus host disease (GVHD) occurs in 7–9% of IT recipients, likely due to the large volume of lymphoid cells accompanying the graft.[41] Multivisceral graft recipients tend to be more likely than isolated IT recipients to develop GVHD.[42] GVHD can present in an early/acute (<100 days) or late/chronic (>100 days) form.[43] Clinically, the skin is the most common organ system affected, with a typical maculopapular rash, pruritus and pain. Patients can develop bone marrow suppression. The transplanted organs themselves are not involved but native organ involvement can occur.[44] Definitive diagnosis can be made with histopathologic correlation. Because the skin is most common organ involved, cutaneous biopsy of an affected skin site can aid in the histologic diagnosis of GVHD. If solid organ involvement is suspected, MDCT with IV contrast is performed to aid in targeting site of biopsy.[41]

Vascular complications

Vascular complications include thrombosis, anastomotic hemorrhage, pseudoaneurysm and stricture. Thrombosis can be either arterial or venous and can result in graft ischemia/infarction requiring at least a partial enterectomy. Pseudoaneurysm formation most commonly occurs near the anastomosis and commonly requires surgical revision or a stent graft.[28] The development of a pseudoaneurysm can be best prevented by secure closure of the anastomosis between the donor SMA and recipient aorta.[28] Vascular strictures are uncommon; venous strictures occur more frequently than arterial strictures (Figure 13).[45] For the evaluation of suspected arterial and venous complications of the intestinal allograft, we utilize contrast enhanced CTA or CTV for initial evaluation due to its relative availability, short imaging times and high spatial resolution. MRA and MRV are utilized in the setting of contraindication to iodinated contrast but in the acutely ill patient may be more challenging to acquire high quality images. We personally have found limited utility for ultrasound evaluation of the arterial supply and venous drainage of the intestinal graft but in the setting of MVT, ultrasound is useful in the evaluation of the transplanted liver and/or pancreas vasculature. Catheter angiography should be reserved for emergent indications, equivocal imaging findings or for treatment purposes (Figure 14).

Recurrence of tumor

In the pre-transplant patient, tumors such as desmoid and neuroendocrine tumors which may primarily involve the root of the mesentery have a tendency to invade adjacent vasculature, making surgical resection nearly impossible. The most recent IT data show that 17% of adults have neoplastic disease as their indication for transplant.[46] In a series of 21 patients at the University of Miami, 6 patients who obtained an IT with neoplastic disease as their indication had recurrence of the neoplasm (Figure 15).[47] In the cases of desmoid tumor recurrence, all occurred in the recipient native tissues and not the allograft itself and were subsequently resected if possible without negative effect on the allograft. For neuroendocrine tumors, there is limited data available. A single center study of 13 patients who underwent MVT for treatment of primary abdominal neuroendocrine tumor demonstrated recurrence in 5 of 12 patients who survived surgery. One patient had recurrent disease in the liver and another in mediastinal lymph nodes; both of these patients succumbed to their disease. The remaining three patients had asymptomatic recurrence with

the sight of recurrence not specified and were described as healthy and functional.[48]

When recurrence of tumor is suspected, MDCT with IV contrast of the thorax, abdomen and pelvis is our initial screening study of choice. Non contrast CT of the thorax and MR of abdomen and pelvis is preferred for patients with contraindications to iodinated contrast. The utility of further imaging is driven both by findings on the CT as well as the type of original malignancy. We have found Indium-111 octreotide scan and, more recently, gallium-68 dotatate PET-CT useful in the evaluation of neuroendocrine tumor recurrence and monitoring of therapeutic response.

CONCLUSION

IT in isolation or as part of a MVT is the definitive treatment of intestinal failure. Radiologists who encounter the IT transplant patient must be familiar with the typical post-operative anatomy and imaging appearance of IT. Equally important is an understanding of the wide range of potential complications after IT, including infection, rejection, mechanical bowel complications, vascular compromise and neoplastic conditions such as PTLD. The Radiologist plays an essential role in screening this patient population for complications and directing the appropriate workup. Imaging and accurate interpretation of the imaging are both critical in the detection and diagnosis of many of the complications seen after IT.

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