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REVIEW

Post-lung transplantation abdominopelvic complications: the role of multimodal imaging

Farouk Dako[1] · Partha Hota[2] · Mansoor Kahn[1] · Maruti Kumaran[1] · Omar Agosto[1]

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Abstract

Lung transplantation (LT) is an established method for treating end-stage lung disease. Although most of the post-lung transplant imaging surveillance is focused on chronic lung allograft rejection, abdominopelvic complications have been reported in 7–62% of patients. The reported wide range of post-LT abdominopelvic complications is thought to be secondary to lack of current standardized definitions. These complications encompass a heterogeneous group of disorders including upper and lower gastrointestinal (GI) disorders, inflammatory conditions of solid organs, lymphoproliferative disorders, and neoplasms; each with varying pathophysiology, timing, severity, and treatment. Clinical manifestations of these complications may overlap or be masked by immunosuppression; therefore, imaging plays a paramount role in the early management and treatment.

Keywords Abdominal complications · Lung transplant · GI · Post-transplant · Imaging

Introduction

Lung transplantation (LT) is an established method for treating end-stage lung disease with common etiologies including: chronic obstructive pulmonary disease (COPD), pulmonary fibrosis, cystic fibrosis (CF), alpha-1 antitrypsin deficiency, and pulmonary hypertension [1, 2]. While most of clinical surveillance and literature is focused on the management of acute and chronic lung allograft dysfunction [3], abdominopelvic complications of LT are comparatively less well-described. These complications encompass a heterogeneous group of disorders including upper and lower gastrointestinal (GI) disorders, inflammatory conditions of solid organs, lymphoproliferative disorders, and neoplasms (Table 1); each with varying pathophysiology, timing, severity, and treatment. Clinical manifestations of these complications may overlap or be masked by immunosuppression; therefore, imaging plays a paramount role in the early management and treatment [4, 5]. Although post-LT abdominopelvic complications have been reported in 7–62% of patients, much of the data is disjointed among the thoracic, abdominal, and transplant literature with imaging information often arriving in piece-meal. The purpose of this review article is to consolidate this information and to introduce the reader to several post-LT abdominopelvic complications as well as to describe their unique features on multimodal imaging (radiography, ultrasound (US), computed tomography (CT), magnetic resonance imaging (MRI), and scintigraphy). With continued yearly growth in prevalence of LT [6, 7], it is increasingly important to understand these post-transplant abdominal complications to best guide management.

Definition

The wide incidence of post-LT abdominopelvic complications (7–62%) [8–13] is thought to be secondary to lack of current standardized definitions. While some authors define all GI tract-related complications as post-LT complications [9, 12, 14], others only define complications as those conditions which jeopardize survival [10], require surgical consultation [13, 15], or intervention [11]. Several classification systems may be used to determine the need for post-LT surgical intervention, with one of the most common being the Dindo–Clavien classification which grades post-surgical complication severity from grade I–V [8, 9]

✉ Farouk Dako
fdako123@gmail.com

[1] Department of Radiology, Temple University Hospital, 3401 North Broad Street, Philadelphia, PA 19123, USA

[2] Department of Radiology, Brigham and Women's Hospital, Boston, MA, USA

Table 1 Overview of abdominal complications after lung transplantation

Upper gastrointestinal complications	Esophageal motility disorders, gastroparesis, gastroesophageal reflux disease, peptic ulcer disease
Lower gastrointestinal complications	Acute colonic pseudo-obstruction, acute mesenteric ischemia, infectious enteritis and colitis, acute diverticulitis, small bowel obstruction
Inflammatory disorders	Cholecystitis, pancreatitis, hepatitis
Neoplasms	Post-transplant lymphoproliferative disorders, other neoplasms
Miscellaneous	Pneumatosis intestinalis, superior mesenteric artery syndrome

Table 2 Dindo–Clavien classification of surgical complications

Grades	Definition
Grade I	Any deviation from the normal post-operative course without the need for pharmacological treatment or surgical, endoscopic and radiological interventions. Allowed therapeutic regimens are: drugs as antiemetics, antipyretics, analgetics, diuretics and electrolytes and physiotherapy
Grade II	Requiring pharmacological treatment with drugs other than such allowed for grade I complications
Grade III	Requiring surgical, endoscopic or radiological intervention
IIIa	Intervention not under general anesthesia
IIIb	Intervention under general anesthesia
Grade IV	Life-threatening complication requiring IC/ICU-management
IVa	Single organ dysfunction (including dialysis)
IVb	Multiorgan dysfunction
Grade V	Death of a patient

(Table 2). Surgery is usually reserved for grade III and IV complications. Surgical intervention for these complications is required in 5–21% [8–11, 14, 16] of patients with the 30-day mortality following intervention ranging from 9 to 35% [13–15]. Despite this associated mortality, early surgical intervention is supported when clinically indicated [13, 17]. The majority of post-LT abdominal complications are non-surgical, often treated empirically based on symptoms [12].

Timing

Post-LT abdominopelvic complications can be divided into early complications (occurring ≤ 30 days post-LT) and late complications (occurring > 30 days post-LT) [8, 9, 13–15] It is, however, important to note that most complications may present in either the early or late post-operative period. While early studies reported a higher incidence and similar mortality of late versus early complications [13, 14], more recent data has shown a higher incidence of early complications and increased mortality [8, 10, 11].

Risk factors

Risk factors that predict post-LT abdominopelvic complications including underlying systemic disease, age, transplantation type, surgical technique, immune status, medication [9, 10, 18]. CF is associated with several abdominal pathologies such as distal intestinal obstructive syndrome (DIOS), gastroparesis, and pancreatitis which in the post-operative setting could be related to either the primary pathology or a complication of transplantation [19, 20]. Alpha 1 antitrypsin deficiency has been associated with an increased incidence of 90-day laparotomy when compared to other pre-LT pathologies which may in part me due to systemic effects of this disorder [21]. It is important to understand that the correlation between pre-LT lung disease and post-LT complication is confounded by the systemic disorder often associated with the lung disease such as could be the case with CF and Alpha 1 antitrypsin deficiency. A patient's pre-LT lung disease has not been found to be a consistent prognostic factor for post- LT complications in at least one meta-analysis [22].

While age is an independent risk factor for long term survival after LT [23, 24], several studies have shown no difference in perioperative mortality based on patient age [24, 25]. Double LT has been shown to be associated with a higher rate of abdominal complications compared to single LT [9, 10]. Damage or irritation of the vagus nerve which lies in close proximity to the dorsal aspect of the recipient's

bronchus has been proposed as a potential mechanism for several underlying abdominal complications with double LT thought to have increased potential for bilateral vagus nerve injury [9, 10, 22]. In addition, increased perioperative complications may be secondary to longer surgical time in the setting of double LT [9, 10]. Cardiopulmonary bypass during LT [26] has also been implicated in the development of post-surgical abdominal complications [26, 27].

Upper gastrointestinal complications

Upper gastrointestinal (UGI) disorders represent the most commonly reported post-LT abdominal complications and encompass a group of conditions including esophageal motility disorders (EMD), gastroparesis, gastroesophageal reflux disease (GERD), and peptic ulcer disease (PUD). Many of these conditions are thought to be due to a combination of damage to the vagus nerve, medications such as opioids and immune modulators, and underlying systemic diseases [9, 28]. These disorders have been shown to occur in both the early and late post-operative periods [8]. Severity can range from mild symptoms requiring only empiric medical treatment to life-threatening conditions requiring surgical interventions [29].

Esophageal motility disorders

EMDs have a high prevalence in the pre-LT setting which increases after LT, reportedly ranging from 49 to 77% using high-resolution manometry and pH impedance data [30, 31]. Although EMDs are associated with GERD, they have been showed to be independent risk factors for development of chronic lung allograft dysfunction, particularly in the presence of esophageal junction obstruction and/or a hypercontractile esophagus [31, 32]. EMDs have been implicated as a risk factor for GERD due to increased esophageal transit of reflux material [32, 33].

Although high-resolution manometry is the gold standard for evaluation of EMDs [32], non-invasive esophagram can reveal stigmata of dysmotility including morphologic changes such as a dilated esophagus with distal tapering, functional changes such as hyper or hypo contractility and proximal reflux of contrast [34]. Treatment for EMDs is largely pharmacological and focused on symptomatic relief [34]. However, in cases of gastroesophageal junction obstruction, Botox injection, endoscopic pneumatic dilatation and a myotomy can be performed [32, 34]. These treatments may worsen GERD due to decreasing competency of the gastroesophageal junction and careful evaluation for reflux of contrast on esophagram studies is necessary in such situations [32].

Gastroparesis

Gastroparesis is a common post-LT complication and seen in 57% of patients [35] with risk factors including CF, diabetes and early post-operative medications [35, 36]. The incidence of gastroparesis increases with time following surgery [36]. Preoperative evaluation for gastroparesis is essential and is typically performed with gastric emptying scintigraphy when clinically suspected [37]. Abdominal radiographs have been shown to be a good initial post-operative study when gastroparesis is suspected [36]. A distended stomach, while nonspecific, is commonly observed [36]. If gastroparesis is suspected, confirmation with a gastric emptying scintigraphy should be performed [37] (Fig. 1).

In patients who are unable to maintain oral nutrition despite medical management, enteric feeding typically with a jejunostomy tube, is preferred in order to deliver nutrition beyond the Ligament of Treitz [38]. While gastric electrical stimulation has been shown to improve symptoms in patients with diabetic gastroparesis and be placed pre-operatively, it is not effective in patients with post-surgical gastroparesis [38].

GERD

Although GERD is present at a higher rate in the pre-transplant cohort, its prevalence has been shown to increase after lung transplantation [29, 39] with an prevalence in the post-LT setting as high as 51–69% [33, 39, 40]. The development of GERD in the post-LT setting has been associated with both esophageal dysmotility and gastroparesis [33]. Aspiration of gastric contents secondary to GERD has also been implicated in the development of bronchiolitis obliterans syndrome (BOS), the most common form of chronic lung allograft dysfunction [29, 33, 35]; therefore, careful pre- and post-operative evaluation and management is essential.

Imaging evaluation for GERD is traditionally performed with a water-soluble-iodinated or barium esophagram and is routinely performed both pre- and post-operatively in some institutions [37]. Gastroesophageal reflux is demonstrated on esophagrams as retrograde reflux of contrast superiorly through the lower esophageal sphincter into the esophagus and in severe cases into the oropharynx [41]. Fundoplication in the pre- or post-operative setting is not uncommonly performed to mitigate injury to the lungs caused by aspiration of gastric contents [29, 39].

Peptic ulcer disease

Peptic ulcer disease (PUD) is an often severe post-LT complication with reported prevalence of 1–4% [14, 19] and represents the most common cause of post-LT GI bleeding [42]. While the incidence of post-LT PUD has decreased

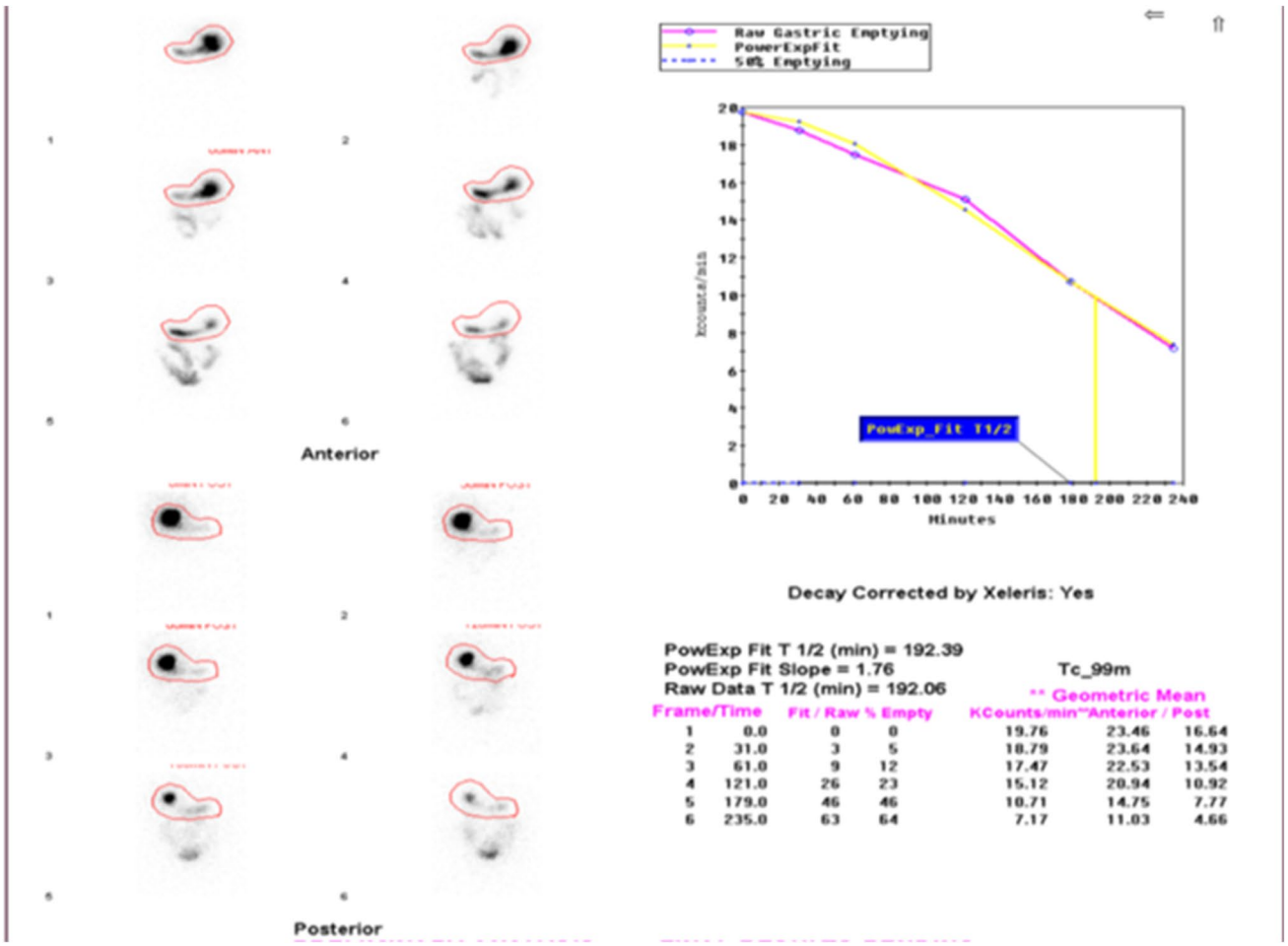

Fig. 1 A 64-year-old male with bloating and vomiting 15 months after a double-lung transplant. Nuclear medicine gastric emptying study demonstrated 77% and 36% of radiolabeled meal remaining in the stomach at 2 and 4 h, respectively (normal: less than 60% and 10% respectively) in keeping with gastroparesis

in recent years due to routine usage of prophylactic proton pump inhibitors and lower steroid doses [43, 44], it still represents up to 11% of early severe post-LT abdominal complications [10]. While the presence of traditional PUD risk factors such as *H. pylori* infection have been implicated in the development of PUD in the pre-LT setting, perioperative hypoperfusion is thought to be a major causative factor in the development of post-LT PUD [42]. Life-threatening complications of PUD include severe GI bleeding and gastric or duodenal perforation.

While endoscopy is the gold standard to diagnose PUD, fluoroscopic upper GI studies may be beneficial in patients who cannot tolerate endoscopic examination [45]. Following administration of either water-soluble or barium oral contrast, erosions and ulcers can be detected using double-contrast technique [46]. Life-threatening complications of PUD such as perforated viscus or bleeding can be readily evaluated on IV contrast-enhanced CT examination. Most PUD is treated empirically with medical management while surgical intervention is reserved for presence of life-threatening complications such as GI bleeding and viscous perforation [10].

Lower gastrointestinal complications

Post-LT lower gastrointestinal (LGI) complications are common and represent the majority of emergent surgical consultations and intervention, particularly in the early post-operative period [8, 11, 15]. LGI disorders encompass several conditions including motility disorders (ileus and acute colonic pseudo-obstruction), bowel obstruction, bowel inflammation (enteritis, colitis and, diverticulitis), mesenteric ischemiaand bleeding [42]. Underlying risk factors are similar to UGI complications and include vagus nerve damage or irritation, post-operative medications, infection, and underlying systemic disorders [9, 28].

Acute colonic pseudo-obstruction (Ogilvie's syndrome)

Ogilvie syndrome, better defined as acute colonic pseudo-obstruction (ACPO) [47, 48] has been reported in up to 30% of post-LT patients [8]. ACPO is thought to develop from either immunosuppression-mediated cytomegalovirus (CMV) infection and/or autonomic imbalance from vagus nerve irritation/damage [47]. Imaging features of ACPO include dilatation of all or parts of the large bowel without mechanical obstruction, predominately involving the cecum, ascending colon and transverse colon, but may also extend to the sigmoid colon and rectum [48]. It is usually not accompanied by dilatation of the small bowel unlike paralytic ileus although distal small bowel dilatation could be seen in cases with incompetent ileocecal valve [49]. Differentiating ACPO from ileus in the post-operative setting is important due to the potential for bowel perforation in ACPO [48–50]. Abdominal X-ray could be suggestive of a diagnosis as the right lateral decubitus view may show distention of the distal colon in ACPO as opposed to in the presence of mechanical large bowel obstruction. CT of the abdomen with intravenous contrast is, however, the modality of choice to different ACPO from other causes of large bowel dilatation and evaluate for complications [48] (Fig. 2).

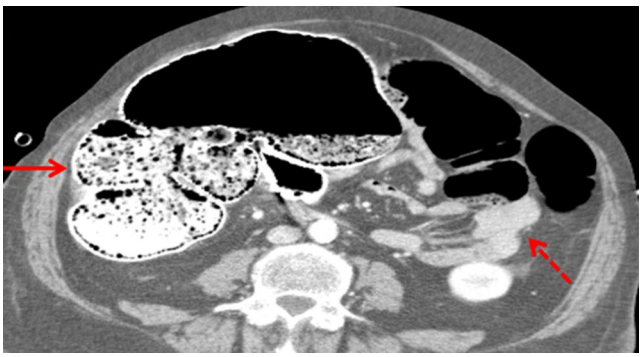

Fig. 2 A 69-year-old male with abdominal distention following recent double-lung transplant. Abdominal CT of the abdomen with IV contrast showed diffused dilatation of the colon, worse in the cecum (red arrow). Small bowel loops were not dilated (dashed arrow), supporting a diagnosis of acute colonic pseudo-obstruction. The patient was managed medically and symptoms resolved 1 week later

Acute mesenteric ischemia

COPD due to smoking is a common indication for LT with smoking also implicated in the development of mesenteric atherosclerotic calcification, a known risk factor for post-operative bowel ischemia [51]. Additional perioperative factors that result in a low-flow state such as prolonged cardiopulmonary bypass and low-cardiac output further increase the risk of mesenteric ischemia particularly in the early post-operative period [42]. It is important for radiologists to have a high suspicion for this complication as clinical and laboratory signs might be masked due to immunosuppression and mechanical ventilation and sedation of the patient [27, 42]. At our institution, preoperative abdominal CT with IV contrast is often performed for high-risk patients to evaluate the mesenteric vasculature and anticipate potential complications (Table 3). Early diagnosis and intervention is important due to an associated high mortality of 50–69% [42, 52]. Imaging findings on IV contrast-enhanced CT of the abdomen include bowel wall thickening and abnormal enhancement, mesenteric fluid, pneumatosis intestinalis and portal venous gas [52] (Fig. 3).

Infectious enteritis and colitis

Infectious colitis is commonly caused by CMV or *Clostridium difficile* (C. *diff*). CMV infection of the GI tract after LT is a well-known complication due to immunosuppression resulting in reactivation of the latent virus [53]. CMV can affect any portion of the GI tract with the esophagus and colon most commonly implicated [54, 55]. CMV colitis has nonspecific imaging features in the colon but is usually segmental in distribution [54, 56, 57] although pancolitis, similar in distribution C. *diff* infection, can be rarely noted on CT

Table 3 Common pre and post lung transplant gastrointestinal imaging studies

Study	Indication
Fluoroscopic speech study	Routinely performed prior to LT to exclude the presence of aspiration. Performed after LT as clinically indicated to exclude aspiration
Fluoroscopic esophagram	Routinely performed prior to LT to exclude the presence of gastroesophageal reflux and severe dysmotility. Performed after LT as clinically indicated
Nuclear medicine gastric emptying	Performed in the setting of clinical concerns for gastroparesis pre- and/or post-LT
Abdominal X-ray	Often the first study performed to evaluate for signs of post-LT dysmotility or obstruction
Abdominal CT	Performed in select patients pre-LT to assess degree of mesenteric artery atherosclerotic calcifications and narrowing. Low threshold for performing to evaluate for post-LT complications
Abdominal ultrasound	Performed in the post-LT setting as first-line study to evaluate biliary pathology
PET-CT	Performed for staging PTLD and evaluating treatment response

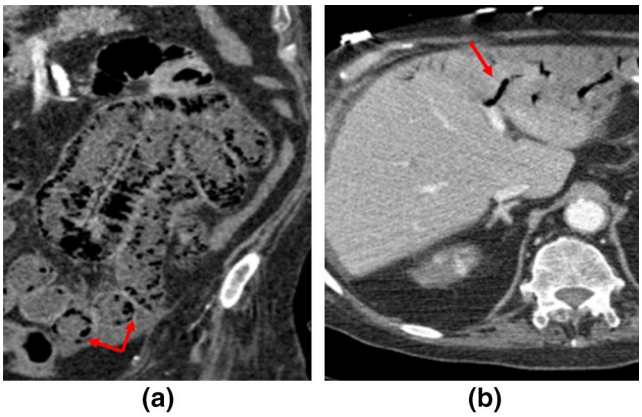

Fig. 3 A 69-year-old male with fever and abdominal pain 1 week status post double-lung transplant. CT abdomen with IV contrast demonstrates extensive pneumatosis intestinalis within loops of small bowel on coronal views (arrow) with adjacent mesenteric fluid (**a**) and portal venous gas (arrow) (**b**) compatible with acute bowel ischemia. Small bowel resection was performed

[58]. The most specific CT imaging features of CMV colitis is colonic wall thickening, particularly if the thickening is associated with mural ulceration [54] (Fig. 4). Ganciclovir is typically used for the treatment and prophylaxis of CMV infections [55].

Other abdominal opportunistic infections due to immunosuppression include other herpes simplex viruses, fungi such as *Candida* and *Mucormycosis*, bacteria such as *Nocardia* and parasites such as *Strongyloides stercoralis* [55]. Infection by these organisms can affect the GI tract and solid organs especially when disseminated [55].

Acute diverticulitis

Diverticulitis has a higher incidence in post-LT patients compared to the general population, likely due to immunosuppression, with a reported rate of 4.5% [59]. It typically occurs within the first 2 years after LT but not during the early post-LT period [59, 60]. It can be managed medically or surgically although a majority of the reported cases required surgical intervention which confers a worse prognosis [9, 59, 60]. In one study, complicated diverticulitis was the most common reason for abdominal surgery after discharge from initial LT hospitalization, affecting 3% of LT patients [60].

Abdominal CT with IV contrast is best suited for evaluation of diverticulitis and typically demonstrates segmental wall thickening and hyperemia with stranding of the pericolic fat [61]. Findings suggesting complicated diverticulitis include per-colonic abscess, pneumoperitoneum, obstruction, and fistula (colovesicular, colocutaneous, colovaginal) formation [61] (Fig. 5). Patients requiring surgical intervention are more likely to have a previous history of diverticulitis and to have CT scan findings consistent with more severe disease [59]. For select patients with recurrent diverticulitis, a prophylactic operation before the transplantation can be considered [60, 62].

Small bowel obstruction

Small bowel obstruction (SBO) is a prevalent abdominal complication and need for surgery particularly in patients who underwent transplant for CF [13, 19, 20]. Most of these patients are found to have distal obstructive intestinal syndrome (DIOS) [13, 19, 20], a sequela of CF found to occur in 10–20% of LTs for CF [19, 20]. The increased incidence of DIOS after LT is largely thought to be due to poor compliance with pancreatic enzymes as a result of improved respiratory symptoms following LT [19]. Prior abdominal surgery is also a known risk factor for developing SBO in the post-LT setting [11, 13]. Most of the reported cases of SBO occurred > 30 days after LT and required surgical

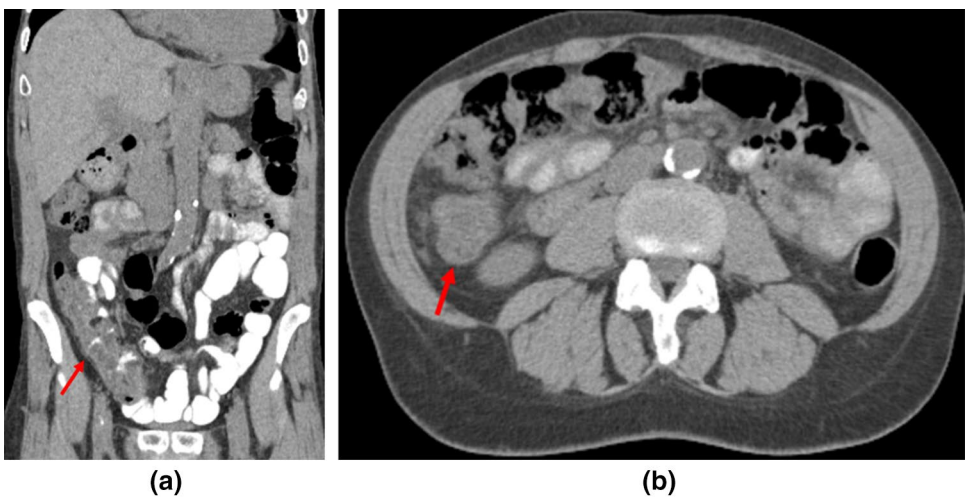

Fig. 4 A 57-year-old female with diarrhea 6 months after double-lung transplantation. CT of the abdomen with oral contrast in coronal (**a**) and axial (**b**) views shows circumferential thickening of the ascending colon with mild adjacent inflammatory changes (arrow) in keeping with colitis. The patient had known CMV infection and was treated successfully with Gancyclovir

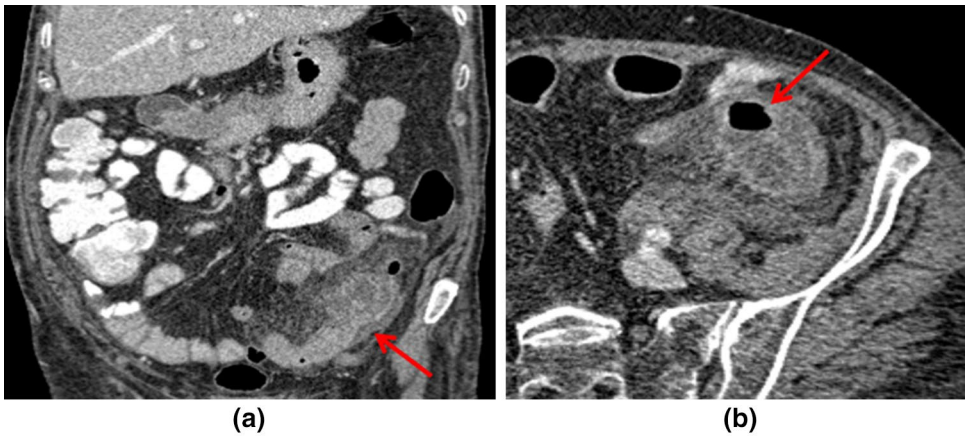

Fig. 5 A 75-year-old female presented with fever 4 months after double-lung transplantation. CT of the abdomen with IV contrast demonstrates inflammation of the distal descending colon on coronal view (arrow) (**a**) complicated by a focal contained perforation on axial view (arrow) (**b**). The patient underwent a partial colectomy

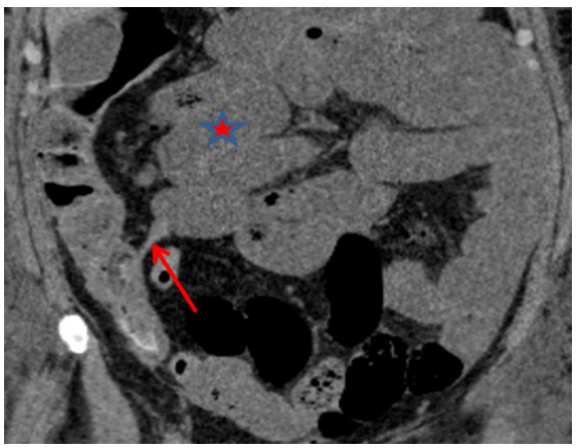

Fig. 6 A 71-year-old female who presented with abdominal pain 3 weeks after double-lung transplantation. CT of the abdomen without IV contrast-demonstrated multiple dilated fluid-filled loops of small bowel (asterix) with transition point in the right lower quadrant (arrow). The patient was taken to the operating room and found to have ischemia of the distal ileum. Small bowel resection was performed

intervention, most commonly lysis of adhesions [11, 14]. The hallmark imaging finding of SBO is dilated small bowel (2.5–3 cm) proximal to the site of obstruction with decompressed distal bowel [63] (Fig. 6). Imaging findings of DIOS include findings of SBO and a bubbly soft-tissue mass in the right lower quadrant [19, 20]. Although SBO can be suggested on abdominal X-ray, CT of the abdomen with IV contrast is preferred for diagnosis and evaluation of complications [63].

Inflammatory disorders

Post-LT extra-intestinal inflammatory conditions include cholecystitis, pancreatitis, and hepatitis [9, 14, 15]. They are multifactorial in etiology with drug toxicity and underlying systemic diseases being the most known culprits [9, 14, 15].

Cholecystitis

Biliary pathology is the most common inflammatory disorder and frequently requires surgical intervention especially in the early post-LT period [9, 14, 15]. Risk factors for developing gallstones specific to the post-LT status include the use of the immunosuppressive drug cyclosporine which is known to cause cholestasis and corticosteroid-induced obesity [64–66]. A high suspicion for acute cholecystitis in the early-LT period must be maintained and emergent abdominal US should be performed for initial evaluation. Definite diagnosis of acute cholecystitis can be made on US in the presence of high-specificity findings such as cholelithiasis and sonographic murphy's sign (Fig. 7); however, a nuclear medicine HIDA scan can be obtained for indeterminate cases [67]. Cholelithiasis without acute cholecystitis is most frequently noted in the late LT period and colic symptoms can be related to chronic cholecystitis [11].

Hepatitis

Hepatitis after LT is thought to result from drug toxicity and is usually of minimal to no clinical significance [9]. Of note, hyperbilirubinemia is a common finding in LT patients but is usually due to systemic processes such as sepsis [68] with rare causes including hemophagocytic lymphohistiocytosis, thrombotic microangiopathy, and ischemic cholangiopathy [68, 69]. Imaging features of hepatitis are nonspecific and can be seen with other systemic disorders. Periportal edema and hepatomegaly are supportive findings on abdominal ultrasound and contrast-enhanced CT [70].

Pancreatitis

The incidence of pancreatitis is increased after LT with a reported rate of 1–3.4% [9, 15]. Most the cases of pancreatitis are not associated with gallstones and are thought to be a combination of immunosuppressive medications

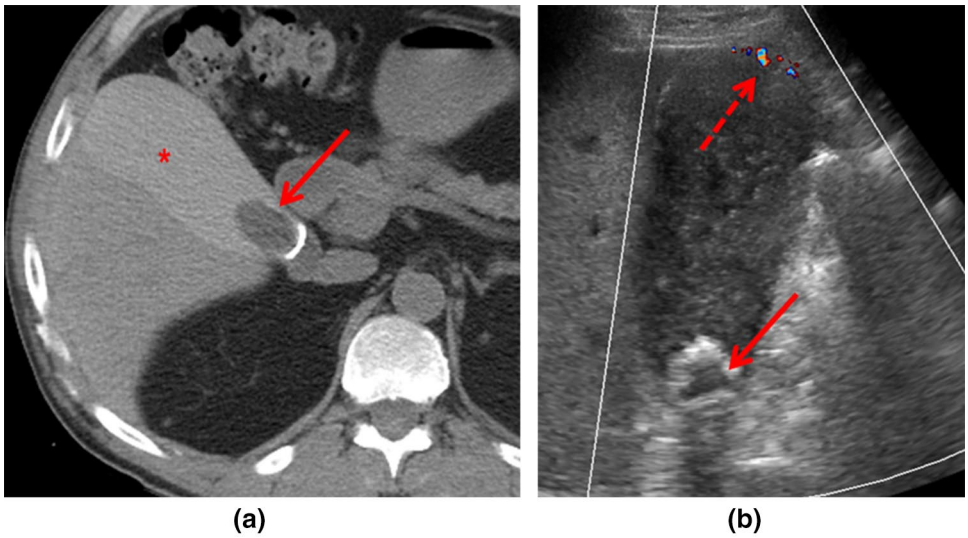

Fig. 7 A 61-year-old male 1 month following a left lung transplant with abdominal pain. CT of the abdomen without IV contrast (**a**) demonstrates a distended gallbladder containing sludge (asterisk) and a peripherally calcified calculus (solid arrow). Concurrent sonographic image (**b**) demonstrates a distended gall bladder with mural hyperemia (dashed arrow) and shadowing obstructing calculus (solid arrow). A positive sonographic murphy's sign was elicited. The patient underwent a cholecystectomy

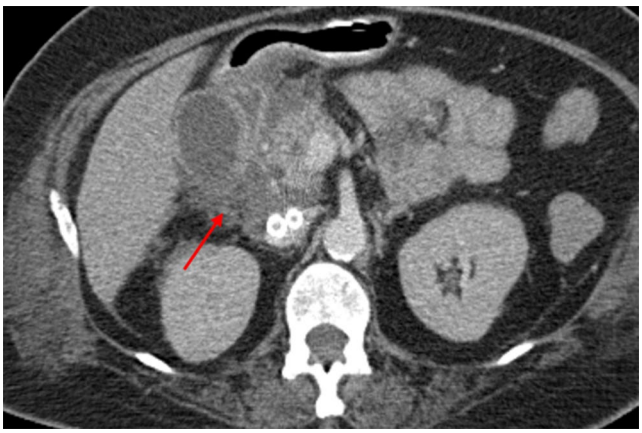

Fig. 8 A 62-year-old female with abdominal pain 2 weeks after right lung transplantation. CT of the abdomen with IV contrast image demonstrates peripancreatic inflammation around the pancreatic head (arrow) in keep with groove pancreatitis. No obstructing biliary calculus or mass was noted. The patient was treated medically

and underlying diseases such as CF [9, 14, 15]. Most are managed medically with the need for surgical intervention conferring a worse prognosis. In the post-LT period, the typical symptoms and lab values of pancreatitis might be absent, thus, contrast-enhanced CT of the abdomen should be obtained urgently if there is clinical suspicion [71]. Imaging features include pancreatic edema and enlargement, peripancreatic inflammatory changes and in more severe cases, necrosis in and around the pancreas [72] (Fig. 8).

Neoplasms

Neoplasms after solid organ transplant are related to immunosuppression which carries an inherent risk of malignancy [73]. Its incidence is noted to be even higher in LT, likely due to the need for greater immunosuppression [73]. The percentage of patients dying from malignancy is growing with increasing survival time, from 3% of all patients during the first-year post-transplant to 14.5% after 5 years [73, 74]. The most frequently noted neoplasms after LT are skin cancer and post-transplant lymphoproliferative disorders (PTLD) [73, 74]. A few studies have reported increased incidence of abdominal neoplasms such as adenocarcinoma of the colon and squamous cancer of the anus [53, 75]. It is important to maintain an index of suspicion for intra-abdominal neoplasms in the post-LT setting (Fig. 9).

PTLD

PTLD represents the most frequently noted post-LT disorder of neoplastic etiology within the abdomen. It is caused by an oncogenic virus, most commonly Epstein Barr virus (EBV) [76–78] which is present in 90–95% of the population [76–78]. CMV infection is another noted viral association [76–78]. The incidence of PTLD in the post-LT setting is 5–15% [76, 79–84], most of which occurs within the first year after transplant [76–78]. One study demonstrated a 3.1% incidence of intra-abdominal PTLD after LT and noted predominant late occurrence (after 1 year) [78]. Extranodal involvement is more common than nodal involvement in intra-abdominal disease with the GI tract and liver the two most commonly affected organs [77, 85]. Nodal PTLD is defined by lypmpadenopathy [77, 86]. The liver is the most frequently involved abdominal solid organ, with involvement seen in 10%, while the GI tract is involved in up to 33% of post-LT PTLDs [77, 80]. The distal small bowel is the most common site of GI tract involvement followed by the proximal large bowel, stomach, duodenum, and esophagus [77, 85, 87].

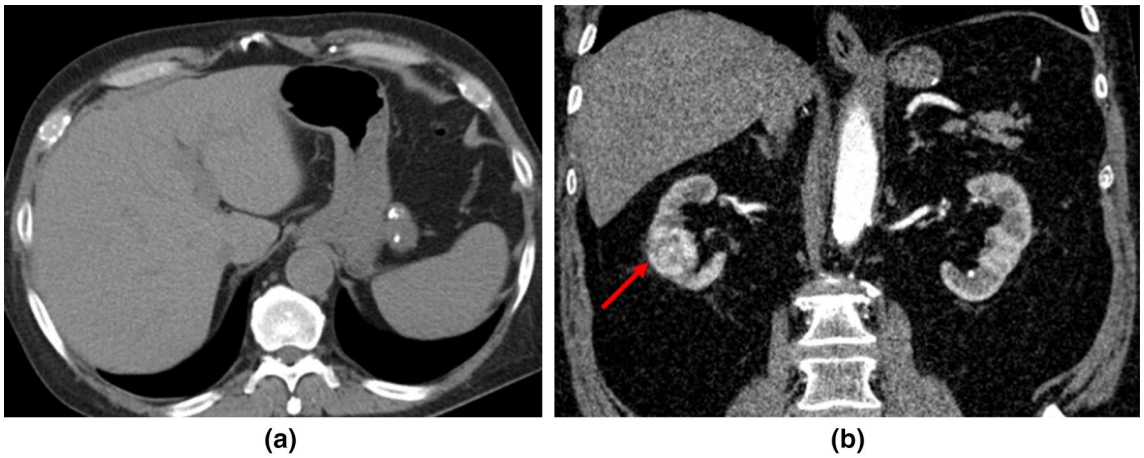

Fig. 9 A 69-year-old male for surveillance 12 years after double LT. CT of the thorax without contrast (**a**) shows an exophytic gastric fundal mass with is partially calcified (arrow). It was surgically resected and found to represent gastrointestinal stromal tumor (GIST). Two years later, CT of the abdomen with IV contrast (**b**) shows a heterogeneously enhancing right renal mass (arrow) which was surgically resected and found to represent renal cell carcinoma

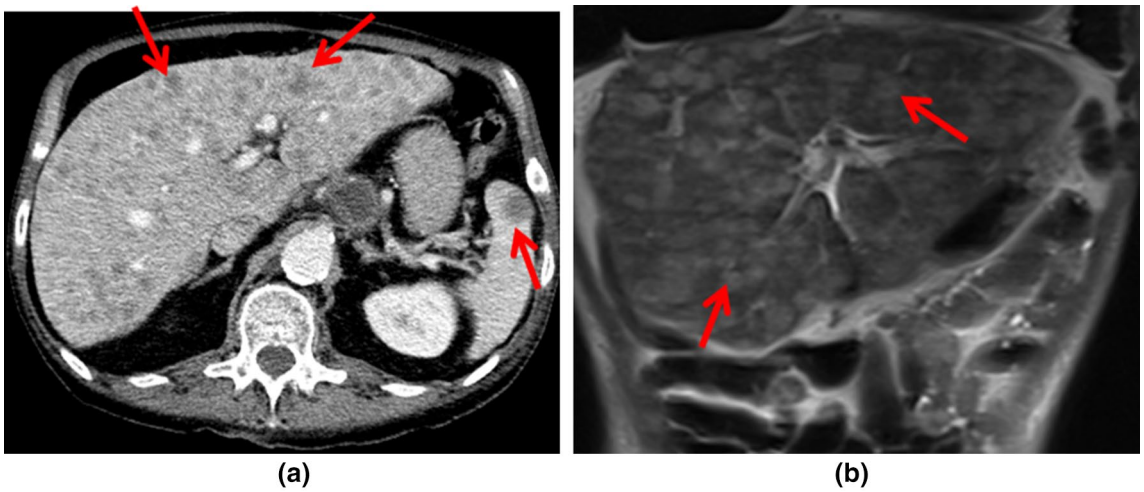

Fig. 10 A 70-year-old male 5 months following left lung transplant with persistent fever and malaise. CT of the abdomen with IV contrast (**a**) demonstrates multiple hypoenhancing lesions in the liver and spleen (solid arrows). Findings are confirmed as numerous hyperintense lesions (solid arrows) on coronal T2-weighted MR images (**b**) representing PTLD which was confirmed on biopsy

Imaging findings of PTLD in the GI tract are similar to findings of lymphoma with an increased rate of ulceration noted [77, 88]. Findings on CT scan vary from wall thickening and dilatation, an eccentric or exophytic mass, luminal ulceration, short-segment intussusceptions and soft-tissue nodules in the peritoneum [77, 85, 89, 90]. Solid organ involvement can be in the form of an infiltrative lesion, multiple small nodules or a solitary mass [86] (Fig. 10). The lesions are typical hypoenhancing on contrast-enhanced CT or MRI and have low-signal intensity on T1- and T2-weighted images [77, 86]. PET-CT scan demonstrates lesions showing increased FDG uptake and can be used for staging and response to therapy [77, 86]. PTLD can progress rapidly to death or regress upon reduction of immunosuppression [76–78]. The radiologist can play an important role in diagnosis, suggestion of biopsy site and follow-up on this disease.

Pneumatosis intestinalis

Pneumatosis intestinalis (PI) with none to mild abdominal physical exam and laboratory abnormalities has been described after LT with an incidence of 2% [91, 92]. It overwhelmingly involves the colon, specifically the ascending and transverse colon [91, 92] with only one case of small bowel involvement noted [91]. Associated

pneumoperitoneum is noted in half of these cases and does not carry any additional prognostic meaning [91, 92]. An overwhelming majority of the cases in these series were treated conservatively with no complications [91, 92].

Although the exact pathophysiology is unknown, multiple theories have been presented including dissection of gas into the bowel wall from increased intraluminal pressure and infiltration of submucosa through mucosa rents by gas forming bacilli [92]. PI with or without pneumoperitoneum noted on radiographs or CT of the abdomen or chest in the post-LT setting can be managed conservatively in the absence of concerning physical examination or laboratory findings with minimal follow-up imaging [91, 92]. It is important for the radiologist to be aware of this uncommon scenario to inform clinicians and collaborate on providing the appropriate management.

Superior mesenteric artery syndrome

Superior mesenteric artery (SMA) syndrome has been described after thoracic surgery including lung transplantation in a few studies [93–95]. In the single study describing two patients with SMA syndrome after LT, the patients were noted to have significant weight loss prior to surgery and both developed symptoms in the early post -operative period requiring only medical management [94]. The diagnosis of SMA syndrome although rare should be considered especially in the setting of weight loss and characteristic imaging features on Fluoroscopic upper gastrointestinal or CT abdomen of dilated stomach and proximal duodenum, with an abrupt transition point at the third part of the duodenum, where the SMA crosses the duodenum. In addition, abdominal CT sagittal views demonstrate reduced aortomesenteric angle and distance of 6–22° and 2–8 mm, respectively [96]. The normal aortomesenteric angle and distance are 28-65° and 10-34 mm, respectively [96].

Conclusion

Post-LT abdominopelvic complications are a common but heterogeneous group of disorders that range from mildly symptomatic to life threatening. When provided with a history of lung transplantation, it is crucial for the radiologist to be aware of these known complications to ensure early diagnosis and to best guide treatment.

Compliance with ethical standards

Conflict of interest The authors have no relevant disclosures.

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