Spectrum of Multidetector Computed Tomography Imaging Findings in Iatrogenic Abdominopelvic Injuries: A Comprehensive Pictorial Review

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Abstract

Keywords
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► iatrogenic injuries
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► pseudoaneurysm
► vascular injuries

Iatrogenic injuries are unavoidable complications of surgeries and minimally invasive procedures. They are generally classified into vascular and nonvascular injuries and based on the time of injury into early and late injuries. Iatrogenic injuries, particularly vascular injuries, increase the mortality and morbidity, with prolongation of hospital-stay. Multidetector computed tomography (MDCT) is a highly sensitive, and often the first imaging modality in suspected iatrogenic injuries. This pictorial review elucidates the imaging considerations and appearances of iatrogenic injuries of the abdominopelvic organs on MDCT.

Introduction

Iatrogenic injuries may be caused by surgical or minimally invasive percutaneous procedures. They may be vascular or nonvascular. Iatrogenic injuries may also be classified as early and late, depending on the time of presentation; early injuries are identified intraoperatively, while late injuries present in the postoperative period. Often under-reported the overall prevalence of iatrogenic injuries due to abdominal surgeries is unknown. The widespread availability of ultrasound and fluoroscopy has led to radiologically guided procedures replacing “blind” procedures. Percutaneous intervention procedures are relatively safe, with an estimated iatrogenic complication of less than 1%, most of which are vascular. However, despite meticulous technique, iatrogenic injuries remain inevitable. Computed tomography is the primary modality for the diagnosis of such iatrogenic vascular and nonvascular injuries. The management of iatrogenic injuries depends on the type and severity of the injury. This is a review of multidetector computed tomography (MDCT) findings in iatrogenic complications associated with commonly performed intra-abdominal procedures/surgeries.

Imaging Considerations

The protocol is tailored according to the suspected site and nature of injury (vascular/nonvascular). For suspected vascular injuries, a noncontrast scan of the region of interest (ROI) is initially obtained to look for hematoma/hemoperitoneum. This is followed by an arterial phase (~35 seconds) scan covering the ROI (CT angiography [CTA]). Subsequently, a scan of the whole abdomen is acquired in the portal venous phase (65–70 seconds). This phase suffices when nonvascular injuries are suspected. For suspected injuries of the pelvicalyceal system/ureter, a delayed scan is obtained at 15 minutes postcontrast injection, to look for urinoma.

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Urinary bladder injuries can be diagnosed by CT cystography,\textsuperscript{5} which is a noncontrast scan after retrograde instillation of positive contrast into the urinary bladder through the Foley’s catheter. Nonionic positive oral/rectal contrast is given in suspected bowel perforation.

**Imaging Spectrum**

**Liver**

Procedures commonly causing hepatic injury include liver biopsy (percutaneous and trans-jugular), percutaneous transhepatic biliary drainage, cholecystectomy, and hepatectomy. The prevalence of major vascular injury following percutaneous procedures of the liver is around 0.16%.\textsuperscript{6} Vascular injuries include hematoma, pseudoaneurysm (PA), arterioporal or arteriohepatic fistula, arterial laceration, and vascular thrombosis. PAs are well-defined contrast-filled outpouchings arising from the injured artery, which may be narrow or wide-necked. Active extravasation is suggested by increase in the size or density of hematoma on venous/delayed phase scan.\textsuperscript{7} In arterioporal fistula, there is shunting of hepatic arterial blood into the portal venous system leading to abnormal opacification of the portal vein/its branches in the arterial phase scan (\textsuperscript{\textbullet}Fig. 1).  

**Biliary System**

The incidence of iatrogenic biliary injuries ranges from 0.1 to 0.6%.\textsuperscript{8} Common causative procedures include cholecystectomy, liver transplantation, endoscopic retrograde cholangiopancreatography (ERCP), hepatic resection, and hepatojejunostomy. Nonvascular injuries of the biliary tract include extra-biliary bile collection (biloma) and biliary strictures. Magnetic resonance cholangiopancreatography is sensitive for biliary injuries. In laparoscopic cholecystectomy, the common bile duct can be mistaken for the cystic duct due to anomalous insertion of the cystic duct.\textsuperscript{8} This leads to inadvertent ligation of the common bile duct, with resultant biliary injury and stricture. Injury to the peribiliary vascular plexus, particularly during liver transplantation, leads to ischemia and development of nonanastomotic biliary strictures.\textsuperscript{8} Iatrogenic strictures are short-segment, symmetrical, with smooth outline, whereas malignant strictures are long-segment (> 12 mm) with irregular outline, and may be associated with metastatic lymphadenopathy.\textsuperscript{10} CT is a useful imaging modality in cases of biloma, which is commonly found in perihpatic locations, with/without obvious communication with the biliary tree\textsuperscript{11} (\textsuperscript{\textbullet}Fig. 2). Vascular injuries include PAs of the right hepatic artery (\textsuperscript{\textbullet}Fig. 3), cystic artery, and common hepatic artery.

**Spleen**

Iatrogenic splenic injuries are extremely rare, with an estimated incidence of 0.00005 to 0.017%.\textsuperscript{12,13} Most commonly seen as a complication of colonoscopy and colonic surgeries, these may also be caused by left nephrectomy, left adrenalectomy, percutaneous nephrolithotomy, left lung biopsy, etc. Lacerations

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**Fig. 1** A 61-year-old male patient with biliary obstruction complained of unbearable abdominal pain while undergoing percutaneous transhepatic biliary drainage (PTBD). Multiphasic computed tomography done in view of suspected iatrogenic injury. (A) Noncontrast scan shows hyperdense perihpatic collection (black star). Positive contrast from PTBD is noted in the left ductal system (arrow). (B) Hyperdense intraperitoneal free fluid is seen (arrow) on noncontrast scan. (C) On arterial-phase scan, there is extravasation of intravenous contrast into the left perihpatic collection (arrow). (D) There is opacification of the left branch of portal vein (thick arrow) on arterial phase. Subtle opacification is also noted in the right branch of portal vein (thin arrow). On portal-venous phase (E and F), there is active extravasation of contrast with layering in the perihpatic collection (arrows).
are the most common injuries, resulting from capsular tear or traction on the splenocolic ligament. These present as linear hypodensities in the splenic parenchyma. More severe injury leads to hematoma and hemoperitoneum.

Pancreas

Iatrogenic pancreatic injuries are mostly nonvascular, with ERCP being the commonest cause of iatrogenic pancreatitis. This is characterized by bulky, heterogeneous pancreas

**Fig. 2**  A 57-year-old female patient presented with vomiting, fever, and upper abdominal pain on postoperative day 4 following open cholecystectomy and perihepatic drain placement. Contrast-enhanced computed tomography was done to rule out intra-abdominal collections. (A) Axial portal-venous phase image showing mild perihepatic collection with surgical drain (arrow). There is mild intrahepatic biliary radicle dilatation (A and B). (C) and (D) Peripherally enhancing collection (star) is seen in the gallbladder fossa, which is suggestive of biloma.

**Fig. 3**  A 35-year-old gentleman presented with hemorrhagic output from subhepatic drain on day 5 of laparoscopic cholecystectomy for cholelithiasis. Multiphasic computed tomography was done to localize the source of bleed. (A) Noncontrast scan of upper abdomen shows a hyperdense collection in the gallbladder fossa (arrow). (B)–(D) Arterial phase images with volume rendering showing a pseudoaneurysm arising from the right hepatic artery (arrows). However, there was no evidence of active extravasation, as shown in the venous phase image (arrow in E). This patient also had a biloma (denoted by star in A–F).
with/without intra/peripancreatic collections. Vascular injuries may result from pancreatectomy, Whipple procedure, and drainage catheter insertion (Fig. 4). Iatrogenic vascular injuries of pancreas have an estimated prevalence of around 3.9%, with pancreatectomy being the most common cause.\textsuperscript{15} The gastroduodenal artery stump is the most common site of bleeding, followed by common hepatic artery, left hepatic artery, dorsal pancreatic artery, and splenic artery.\textsuperscript{15} Early postpancreatectomy hemorrhage (presentation within 24 hours) is due to technical failure, while delayed postpancreatectomy hemorrhage (presentation after 24 hours) is due to anastomotic leakage.\textsuperscript{16}

**Kidneys**

Iatrogenic renal injuries are mostly vascular, with a prevalence of 0.9 to 3%.\textsuperscript{17} Various causative procedures include but are not limited to percutaneous nephrostomy, percutaneous nephrolithotomy, renal biopsy, partial nephrectomy, and antegrade ureteral stenting.\textsuperscript{18} Vascular injuries lead to renal arterial PAs (Figs. 5, 6), arteriovenous fistula (AVF), calyceal hemorrhage (Fig. 7), etc.

**Pelvicalyceal System and Ureters**

Ureters have a long course extending from the pelvicalyceal system up to the urinary bladder. They cross major vessels and lie in close proximity to the uterus, which make them prone to injuries, particularly during gynecologic surgeries.\textsuperscript{19} The incidence of iatrogenic ureteric injuries ranges from 0.5 to 10\%\textsuperscript{20–22} with the distal third being the most common site, accounting for up to 75\% of cases.\textsuperscript{23} In the early phase, these present as urinomas, which appear as hyperattenuating collections on urography, owing to leakage of excreted contrast (Fig. 8). Over time, there is development of fibrosis resulting in strictures, which is often the presentation when detected late. These can also be well visualized on CT urography as segmental smooth narrowing of the ureter. Ureterovaginal fistula is a late complication of ureteric injury, especially after pelvic surgeries.

**Urinary Bladder**

Iatrogenic urinary bladder injuries may be caused by catheterization, cystoscopy, transurethral resection of bladder tumor, etc. and procedures performed on other pelvic organs in relation to the bladder, such as hysterectomy and cesarean section.\textsuperscript{24} In an institutional study, iatrogenic bladder injuries resulted from gynecologic/obstetric, general and urologic surgeries in 65\%, 22\%, and 13\% of cases.\textsuperscript{25} In intraperitoneal injury, there is leakage of contrast into the peritoneal spaces such as the paracolic gutters, rectouterine pouch, and retrovesical space, with contrast outlining the bowel (Fig. 9). This usually happens with injury to the dome of a distended bladder. In extraperitoneal injuries, there is leakage of contrast into the prevesical space (Fig. 10), perineum, scrotum, and thighs.\textsuperscript{26}

**Uterus and Genital Tract**

Iatrogenic uterine injuries are usually vascular and include uterine artery PAs (Fig. 11) and AVF. These have a prevalence of 0.1 to 0.2\%.\textsuperscript{27,28} On CTA, AVFs appear as lesions that opacify in the arterial phase, with subsequent early opacification of the gonadal and/or internal iliac veins. Nonvascular injuries include uterine perforation, rupture, and adhesions.
**Fig. 5** A 35-year-old female patient presented with abdominal distension and hemoglobin drop following biopsy from the left kidney. Axial images in portal-venous phase (A–C) show hyperdense collection in the left perinephric region with layering (star). The left kidney is displaced anteriorly by the collection (block arrow in A). However, bilateral renal arteries were unremarkable and no bleeding source was identified. Axial (D) and coronal maximum intensity projection (E) images depicting the renal arteries, denoted by line arrows.

**Fig. 6** A 47-year-old male patient presented with abdominal pain and gross hematuria following left percutaneous nephrolithotomy. Noncontrast computed tomographic images showed hyperdense contents in the left renal pelvis (A) and in the urinary bladder (B). Arterial phase image (C) showed a pseudoaneurysm in the mid-pole of left kidney (block arrow), arising from the branches of accessory left renal artery, marked by thin arrows in D and E). There was no active extravasation in the venous phase (F).
Fig. 7  Computed tomography urography images of the same patient as in Fig. 6 showed filling defects in the left pelvicalyceal system and urinary bladder, suggestive of hematoma, indicated by block arrows in (A) and (B). (C) Coronal maximum intensity projection of urography showing filling defects in the left pelvicalyceal system (block arrows). The right pelvicalyceal system and ureter were normal.

Fig. 8  A 40-year-old male patient with left nephrolithiasis underwent percutaneous nephrolithotomy following which he presented with abdominal pain and distension. Axial contrast-enhanced computed tomography (CT) shows left perinephric hematoma (arrow in A), with a parenchymal discontinuity in the left kidney (arrow in B) and a collection near the left renal hilum (arrow in C) with perinephric fat stranding. CT urography showed leakage of excreted contrast from the ruptured pelvicalyceal system (PCS) into this collection (arrows in D–F), suggestive of PCS injury with urinoma.
Fig. 9 A 33-year-old female patient presented with abdominal pain, distension, and inability to void following diagnostic hysteroscopy. Urinary bladder injury was suspected and computed tomography cystography was done. (A) Extravesical contrast in the pelvis (black arrow). The urinary bladder was undistended and bulb of Foley’s catheter was noted. (B) Coronal reformatted image showing a rent in the right superolateral aspect of urinary bladder wall (black arrow) with leakage of contrast across it. (C) There was gross ascites with fluid-contrast level (indicated by star). (D) The leaked contrast was extending up to the left paracolic gutter (indicated by star). These findings are suggestive of intraperitoneal bladder injury.

Fig. 10 A 27-year-old male patient presented with abdominal pain and distension following failure of attempted suprapubic cystostomy. (A) Noncontrast computed tomography (CT) section showing air foci and fat stranding in the anterior abdominal wall and prevesical space (arrows). (B) CT cystogram showed leakage of contrast into the prevesical space (arrow). There was no intraperitoneal fluid or contrast leak (C). (D) Sagittal reformatted image showing a rent in the anterior wall of urinary bladder with contrast leak across it (arrow). These findings are suggestive of extraperitoneal bladder injury.
The prevalence of uterine rupture ranges from 0.6/10,000 births in an unscarred uterus to 5.3/10,000 births after cesarean section. Procedures with high risk of uterine injury include cesarean section, hysterotomy, dilatation and curettage, evacuation of retained products of conception, and hysteroscopy. Postpartum vulval hematoma (► Fig. 12) is a complication of episiotomy, with an incidence of 1 per 300 to 1,000 deliveries.

Bowel
Iatrogenic causes of bowel perforation and mesenteric injury are not very common. Perforation rate in diagnostic gastroscopy is reported to be 0.01 to 0.03% and iatrogenic perforation during colonoscopy is reported to be 0.016 to 0.2%. Gastroduodenal perforation is a rare complication of ERCP. Inadvertent gastric perforation can be caused by nasogastric tube insertion, intercostal drainage tube insertion, etc. Iatrogenic rectosigmoid injury is commonly caused by gynecologic surgeries. Free intraperitoneal air outlines the liver, and tracks along the ligamentum teres (ligamentum teres sign), portal vein (periportal free gas sign), and falciform ligament (falciform ligament sign). In the postoperative scenario, it is important to differentiate free intraperitoneal air following laparotomy/ laparoscopy from bowel perforation. Postoperative pneumoperitoneum resolves within 3 days in 81% of patients and is unlikely to persist thereafter; such patients are asymptomatic and clinically stable. In contrast, patients with bowel perforation present with worsening clinical status. Extraluminal oral/rectal contrast is the most sensitive finding in bowel perforation. Perforation of retroperitoneal hollow viscus (duodenum, ascending and descending colon) leads to pneumoretroperitoneum, where-in air outlines the kidneys and perinephric spaces (► Fig. 13).

Abdominal Wall
Iatrogenic complications involving the abdominal wall can be caused by surgical procedures and percutaneous intervention procedures, particularly ascitic tap. Nonvascular complications include but are not limited to incisional hernia, parastomal hernia, collections, wound dehiscence, etc. The reported incidence of iatrogenic hernia is 7.5 to 12%. Vascular complications include inferior epigastric artery PA and rectus sheath hematoma that can extend into the preperitoneal space (► Fig. 14).

Conclusion
Although iatrogenic injuries are unavoidable, some of the ways to limit their occurrence include performing guided procedures to avoid vital structures and vessels, identification of
Fig. 12  A 25-year-old female patient presented with persistent vaginal bleeding and vulval swelling 10 days after vaginal delivery, which was complicated by atonic postpartum hemorrhage. (A) Non-contrast computed tomography shows a hyperdense hematoma in the pelvis displacing the rectum. (B) Curvilinear hyperenhancement was seen within the hematoma on the arterial phase (line arrow) which showed progressive increase in size on the venous phase (line arrow in C). The hematoma was seen extending into the vulva (arrows in D, E). The uterus was bulky with heterogenous attenuation (star in F).

Fig. 13  A 63-year-old male patient presented with severe abdominal pain and vomiting 4 hours after endoscopic retrograde cholangiopancreatography for choledocholithiasis. Axial contrast-enhanced computed tomography images showing (A) pneumoperitoneum with air along the porta (periporal free gas sign) and intrahepatic inferior vena cava (arrow); (B) zoomed image showing air foci along the ligamentum teres (ligamentum teres sign); (C) pneumoretroperitoneum with air in the right perinephric space; a suspicious discontinuity was seen in the junction of second and third parts of duodenum (arrow). (D) Free intraperitoneal air outlining the liver (arrow). There was tracking of free air along the esophageal hiatus (arrow in E) with subsequent pneumomediastinum (arrow in F).
variant anatomy, proper exposure of structures, and avoiding blind clamping of vessels. CT is often the most sensitive imaging modality for identifying both vascular and nonvascular injuries and the protocol should be tailored according to the clinical suspicion. Hence, knowledge of possible iatrogenic injuries and their appearances on MDCT is necessary for timely diagnosis and management.

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Conflict of Interest
None declared.

References

Fig. 14 A 40-year-old female patient with severe abdominal pain and hemoglobin drop after ascitic tap. Biphasic contrast-enhanced computed tomography abdomen was done. (A) Arterial phase image showing heterogeneity in the left anterior abdominal wall with a collection in the preperitoneal space with hyperdense contents (star). (B) There was suspicious extravasation of contrast seen as ill-defined curvilinear hyperdensity within the collection (arrow). (C) Portal venous phase image showing abdominal wall collection with hyperdense contents (star) suggestive of hematoma. (D) There was increase in the density and size of the curvilinear structure on venous phase, which is suggestive of active extravasation.