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REVIEW ARTICLE

Complications of minimally invasive procedures of the abdomen and pelvis: a comprehensive update on the clinical and imaging features

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Abstract Minimally invasive gastrointestinal, genitourinary, and gynecological procedures are widely used in the clinical practice for diagnostic and therapeutic purposes. Complications both minor and major are not uncommon with these procedures. Imaging plays an important role in the detection and optimal management of these complications. Familiarity with the clinical and imaging features of these complications by radiologists can help in their timely detection.

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Introduction

Iatrogenic complications are a major cause of morbidity and mortality. Advances in medicine led to development of sophisticated minimally invasive diagnostic and treatment techniques which have enabled clinicians to decrease the incidence of iatrogenic complications. By definition, minimally invasive procedures result only in minimal biological damage at the point of entry into human body. Empirically minimally invasive procedures in the abdomen and pelvis can be classified into gastrointestinal, genitourinary, and gynecological procedures. Gastrointestinal procedures include endoscopic retrograde cholangiopancreatography (ERCP), laparoscopic cholecystectomy, colonoscopy, and laparoscopic appendectomy. Genitourinary procedures include laparoscopic nephrectomy, transurethral resection of prostate, and urinary catheterization. Dilatation and curettage, hysteroscopy, laparoscopic hysterectomy, laparoscopic myomectomy, and tubal ligation are some of the gynecological procedures.

Nevertheless, a few complications can occur with these procedures which can be diagnosed clinically or may require imaging or can be a surprise finding at imaging performed for other reasons. In this article, we will discuss the clinical presentation and imaging findings of some of the common complications of these procedures. Although multimodality imaging is used at appropriate clinical scenarios, major emphasis will be on computed tomography (CT) as it is usually the first line of imaging in emergency settings.

Endoscopic retrograde cholangiopancreatography

ERCP is a very valuable minimally invasive procedure with lesser morbidity when compared to surgery and with a reported complication rate of 5–10 % [1, 2]. The complication rate is less with diagnostic ERCP as compared to therapeutic ERCP. The most common complications are acute pancreatitis and duodenal perforation. Cholangitis, duodenal hemorrhage, stent migration, and injury to the esophagus, liver, and spleen are the other complications [1]. If a patient has fever, elevated white blood cell count, and severe abdominal pain post-ERCP, CT is usually performed. CT helps to know the type and severity of the complications, in the assessment of prognosis and also in the reassessment of a patient who does not improve with the conservative management of the complication.

Acute pancreatitis and duodenal perforation

ERCP is complicated by acute pancreatitis in 5–10 % of cases [3]. The presence of abdominal pain for more than 24 h post-ERCP with three times elevation of amylase levels is suggestive of pancreatitis. Findings in CT can vary from relatively normal appearance in cases of mild inflammation to focal or diffuse glandular swelling with peripancreatic stranding and phlegmon in severe cases. Pancreatic necrosis shows nonenhancement on contrast-enhanced CT [4]. CT can identify fluid collections and helps in needle aspiration/drainage. Duodenal perforation is a complication seen in 1.3 % of ERCP cases [5]. Free extraluminal retroperitoneal air is the key CT finding with often associated pneumatosis (Fig. 1a, b). Isolated retroperitoneal air at CT does not correlate with the severity of the complication or the need for surgery and can be seen in asymptomatic patients immediately after ERCP. It is important to identify associated fluid collections from biliary or intestinal leak and infections which warrant urgent management in the form of percutaneous drainage, stenting, or surgery [6]. Conservative management could treat acute pancreatitis, whereas surgery may be required to remove the necrotic tissue in severe cases of acute pancreatitis [7].

Duodenal hemorrhage

Duodenal hemorrhage (DH) usually occurs with sphincterotomy. Risk of DH is high in patients with coagulopathies and on anticoagulant therapy. Significant hemorrhage, i.e., melena or hematemesis with an associated decrease in hemoglobin concentration of at least 2 g/dL or need for a blood transfusion, occurs in 2 % of ERCP cases [8]. Delayed DH (>24 h post-ERCP) can be an incidental CT finding. It appears as high-density mass in the duodenal wall with wall thickening (Fig. 1c, d) [9]. It becomes iso- to hypodense as time progresses with pseudocapsule formation. Surgery or embolization may be required in cases of DH due to arterial bleeding. If it is a venous bleeding, it is usually treated with local epinephrine, balloon occlusion, or heat therapy [3].

Infection

Inadequately drained ducts during ERCP can result in bacteremia in 15 % of diagnostic and 27 % of therapeutic cases [10].

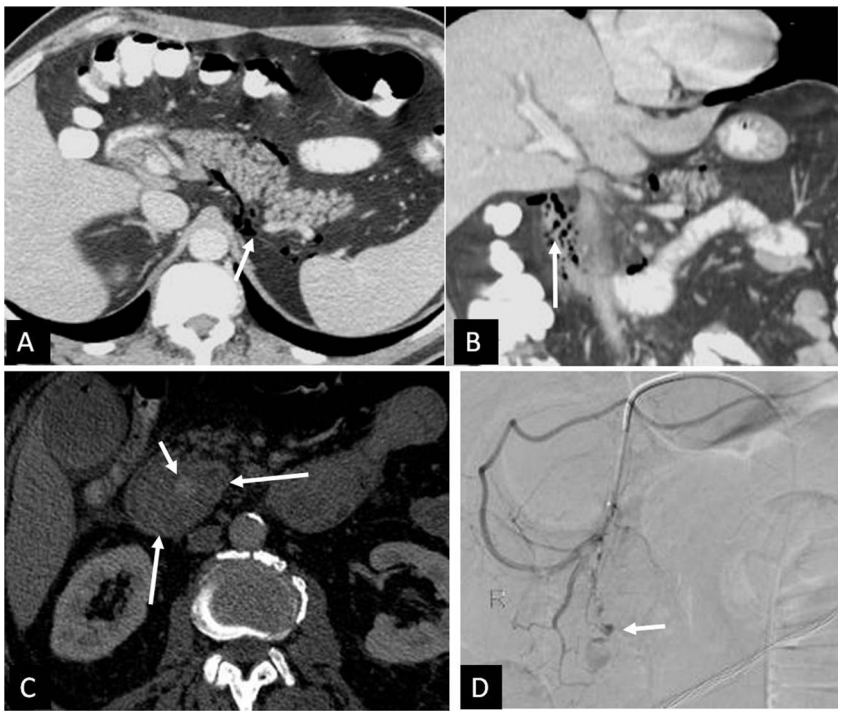

Fig. 1 Fifty-five-year-old man with duodenal perforation post-ERCP. Axial (**a**) and coronal (**b**) contrast-enhanced CT images show free extraluminal retroperitoneal air (*short arrow*) and duodenal pneumatosis (*long arrow*). Sixty-year-old man with duodenal bleed post-ERCP. Axial contrast-enhanced CT (**c**) shows contrast outpouching at the ampulla (*short arrow*) with duodenal mass representing hematoma (*long arrows*). Catheter angiography (**d**) reveals a small pseudoaneurysm (*arrow*) with contrast extravasation in the region of ampulla along the course of superior pancreaticoduodenal artery

Though bacteremia is insignificant, it can complicate into cholangitis in 1 % of the ERCP cases. Pain, fever >38 °C, and elevated leukocyte count are the clinical findings [8]. CT may be performed in patients with cholangitis to rule out liver abscess. Dilated bile ducts, increased attenuation of bile, pneumobilia, duct wall thickening, and enhancement are the CT findings in cholangitis [4]. Hypoattenuating mass with an enhancing capsule is the typical CT appearance of an abscess. Antibiotic therapy should be initiated to treat cholangitis patients.

Miscellaneous

The stents placed in the common bile duct or the pancreatic duct during ERCP can migrate in few cases. Some of the migrated stents get expelled with stool but some do not. CT can find the atypical location of these stents and can be removed endoscopically [11]. Esophageal perforations can occur due to direct contact of the endoscope. Pneumomediastinum, mediastinitis, and extravasation of contrast material are the CT findings in cases of esophageal perforation and usually require surgery for repair [12]. Traction on the gastrosplenic ligament or the direct contact by the endoscope can cause lacerations of the liver and spleen which can complicate into hemoperitoneum requiring surgery.

Laparoscopic cholecystectomy

Laparoscopic cholecystectomy being one of the most common surgical procedures is associated with various complications. Reported morbidity and mortality rates for laparoscopic cholecystectomy (LC) are 1.9 and 1 % as compared to 7.7 and 5 % for open cholecystectomy, respectively. Patients with acute cholecystitis, fibrotic gallbladder, cirrhosis, and obesity are at increased risk of developing complications with LC. Hemorrhage (2.3 %), iatrogenic perforation of the gallbladder (GB) (16 %), common bile duct (CBD) injuries (0.1 %), conversion to open surgery (1.9 %), and injury to other viscera are the intraoperative complications. Bile leak (0.5 %), hemorrhage (0.15 %), subhepatic abscess (0.1 %), retained bile duct stones (0.11 %), and dropped stones (0.08–0.3 %) are the postoperative complications [13, 14]. Few of these complications are reviewed below (Fig. 2) and the detailed discussion of all the complications is beyond the scope of this article.

Biliary injury

Biliary complications include biliary obstruction and leak and are common with an incidence rate of 0.2 to 7 %. Bismuth classification is used to categorize biliary injury based on the site of injury [15]. Biliary obstruction can occur with malpositioned surgical clips, thermal injury, postoperative fibrosis, and retained stones in the biliary system. Small and asymptomatic bile leaks are due to the minor anatomic variants in the biliary system. Symptomatic persistent bile leak is from dislodgement of the clip at the cystic duct stump, aberrant biliary ducts of Luschka, tenting injuries to CBD, lacerations, and clipping of CBD without clipping cystic duct remnant. Associated anatomic variants in biliary ductal system increase the chance of inadvertent biliary injury [16].

Bile duct injuries can clinically present with abdominal pain, jaundice, fever, pale-colored stools, dark urine, and itching. Ultrasound, CT, magnetic resonance cholangiopancreatography (MRCP), and cholescintigraphy are the usual diagnostic tests used in detecting biliary injury. Cholescintigraphy is considered to be more sensitive and specific than CT in detecting minor bile leaks [17]. Recently, MRCP with hepatobiliary-specific contrast is increasingly used to identify biliary leaks with better anatomic detail than cholescintigraphy due to predominant biliary excretion of intravenously injected contrast (Fig. 3) [18]. In biliary leak, fluid collection representing biloma is seen close to the site of injury in the GB fossa or subhepatic location. Biliary contrast leakage from the site of injury into the collection can be seen. In biliary obstruction, intrahepatic and extrahepatic biliary dilatation is seen with sudden interruption in the CBD at the level of injury. Depending on the findings in the above noninvasive tests, invasive tests like transhepatic cholangiography and ERCP are done for diagnostic confirmation and to determine the level of injury for operative planning.

Minor biliary leaks resolve spontaneously and persistent collections can be drained percutaneously. ERCP can be used for stenting in case of bile duct injuries with leak and/or obstruction from fibrosis. Surgery is required in major ductal injury [13].

Dropped gallstones

Spillage of gallstones is reported to occur in 5–40 % of cases of LC; however, complications are rare seen only in 0.08–0.3 % of those cases [14]. Patients with spilled stones can present with abscess, cutaneous sinuses, granulomas, or intestinal obstruction. CT is diagnostic in patients with spilled stones specially when it is radiodense and can detect associated abscess [19]. Because of pneumoperitoneum created during LC, dropped gallstones can reach any part of the abdomen and form a nidus for infection. Careful dissection, aspiration of bile in the gallbladder before dissecting the gallbladder, and the use of retrieval bags are some of the measures that can prevent spillage of stones [20]. Since the clinically significant complications from dropped stones are extremely uncommon, conversion to open cholecystectomy is

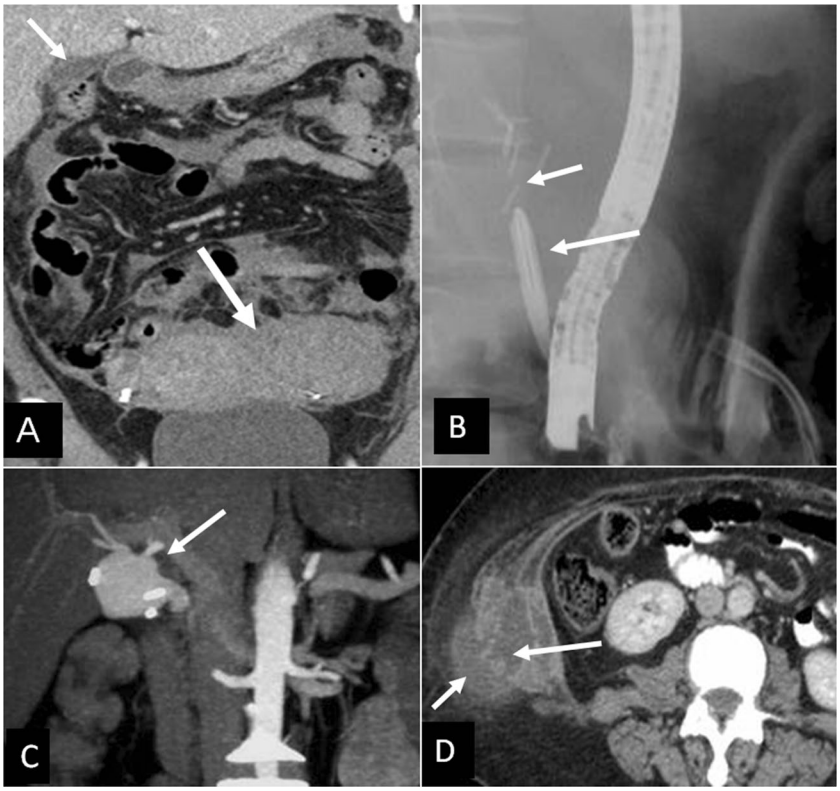

Fig. 2 Complications of laparoscopic cholecystectomy. **a** Fifty-six-year-old female presents with a painful abdomen 3 days after laparoscopic cholecystectomy. Coronal contrast-enhanced CT demonstrates a large omental hematoma (*long arrow*) related to laparoscopy port insertion. Note the postcholecystectomy changes in the gallbladder fossa (*short arrow*). **b** Laparoscopic cholecystectomy complicated by clipping of the proximal-mid-CBD in a 45-year-old woman. The guide wire (*long arrow*) during ERCP could not be passed beyond the clipped segment of CBD with complete cutoff of the CBD. Note the surgical clips in the CBD (*short arrows*). **c** Hepatic artery aneurysm in a 40-year-old female following laparoscopic cholecystectomy. Coronal MIP image of contrast-enhanced CT demonstrates aneurysm coming of the right hepatic artery (*arrow*). **d** Laparoscopic cholecystectomy complicated by dropped gallstone (*long arrow*) with chronic inflammatory mass in the perihepatic space and adjacent abdominal wall (*short arrow*)

not indicated routinely as secondary prevention, but this is still controversial [21]. The abscesses with gallstones are usually treated by local drainage and evacuation of the stones.

Injury to adjacent viscera

During the blind insertion of the trocar, bowel can get injured or bleeding can occur in the abdominal wall or omentum resulting in hematomas [22]. The trocar insertion injury can cause adhesions or hernias which can obstruct the bowel. Bowel injuries can present in the form of perforation or in the form of ileus [23]. Large hematomas can cause compression symptoms or can rupture resulting in hemoperitoneum. Plain X-ray can identify free air and multiple air-fluid levels in cases of bowel perforation and bowel ileus, respectively. CT is helpful in determining the location and severity of bowel injury, ileus, and hematomas [24].

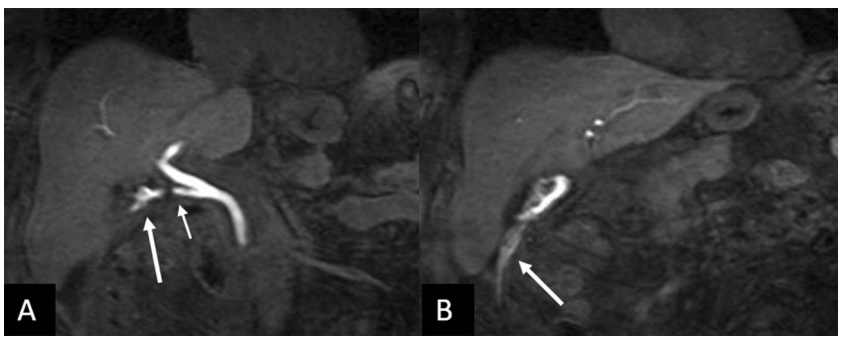

Fig. 3 Laparoscopic cholecystectomy complicated by biliary leak in a 70-year-old woman. **a**, **b** Coronal postcontrast T1W delayed hepatobiliary phase MR images show contrast leak (*long arrow*) from the cystic duct stump (*short arrow*). Note the passage of extravasated contrast along the surgical drain (*long arrow*, **b**)

Vascular injury

Vascular injury usually results in intraoperative bleeding and could be from the cystic artery stump, the right hepatic artery, or rarely the portal vein. Hepatic artery pseudoaneurysm is a rare late complication of LC resulting from the erosions of the clip, direct injury, and/or thermal injury. The most common site is the right hepatic artery (61 % of the cases) [25]. The classic clinical triad of right upper quadrant pain, jaundice, and hemobilia is noticed in only 20–30 % of the cases, and hence, a high index of suspicion is needed to diagnose pseudoaneurysm. Hypoechoic pulsatile mass in the liver with bidirectional flow on Doppler ultrasound is suggestive of pseudoaneurysm [26]. Though CT angiography may identify hemorrhage and pseudoaneurysm, selective celiac and superior mesenteric artery angiography remains the most reliable diagnostic test in patients with pseudoaneurysms. Embolization is the first line of treatment in most patients with vascular aneurysms after LC except in few patients with complex injury or rupture of aneurysm where surgery can be required [27].

Colonoscopy

Colonoscopy is a common procedure performed for screening and diagnostic and therapeutic purposes. Perforation (Fig. 4), hemorrhage, postpolypectomy syndrome (transmural colonic burn without frank perforation), diverticulitis (Fig. 5), and infection are the described complications of colonoscopy. Risk of developing these complications is increased if biopsy or polypectomy is performed during the procedure. Therapeutic colonoscopy has an overall complication rate of 5 % with serious complications (requiring hospitalization) in 2 % of the cases [28].

Perforation

The perforation rate is variable with increased risk after polypectomy or biopsy (0.06 % without biopsy or polypectomy and 0.1 % with biopsy or polypectomy) [29]. Rectosigmoid colon is the most common site for perforation. Patients with perforation present with abdominal pain and distension, fever, and leukocytosis. Perforations of intraperitoneal colonic segments will more often lead to free intraperitoneal air and fluid, whereas perforation of the ascending colon, descending colon, and rectum is more likely to result in extraperitoneal air and fluid. Large amount of air can be detected on plain radiographs. CT will be required to detect small amount of free air and fluid collection especially in contained perforation [30]. Management is based on the site and severity of perforation, peritoneal contamination, and hemodynamic status [31].

Hemorrhage

Hemorrhage occurs more frequently with polypectomy done during colonoscopy (1–2 % of cases) than with a diagnostic colonoscopy (0.1 % of cases) and can be immediate or delayed [32]. Immediate bleeding can be intraluminal or extraluminal. Intraluminal bleeding occurs at the polypectomy site which is detected during the colonoscopy and controlled by cautery, clips, or local epinephrine injections. Extraluminal bleeding is rare and manifests as intraperitoneal hemorrhage and can be seen in remote locations including paracolic gutters, subphrenic spaces, and pelvis. CT can show high-density fluid representing hemoperitoneum and localized hematoma with or without free perforation. Catheter angiography can show active arterial extravasation. Delayed bleeding is seen in CT as localized intramural hematoma. CT angiography and technetium red blood cell scan is used to identify the site of ongoing bleeding in stable patients [31].

Laparoscopic appendectomy

Laparoscopic appendectomy (LA) is one of the most commonly performed emergency surgical procedures. In comparison with open appendectomy, LA is associated with a shorter

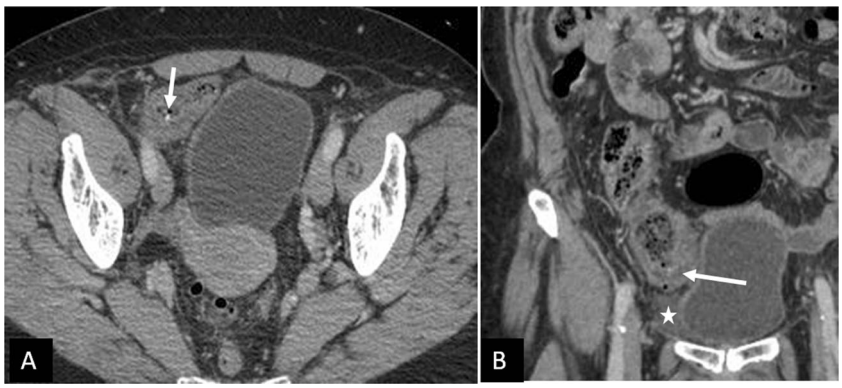

Fig. 4 Postcolonoscopy microperforation of the cecum in a 56-year-old woman. Axial (**a**) and coronal (**b**) contrast-enhanced CT shows few air specks in the edematous cecal wall (*long arrow*) and adjacent free fluid (*asterisk*). Note the presence of high-density clips in the cecal wall (*short arrow*)

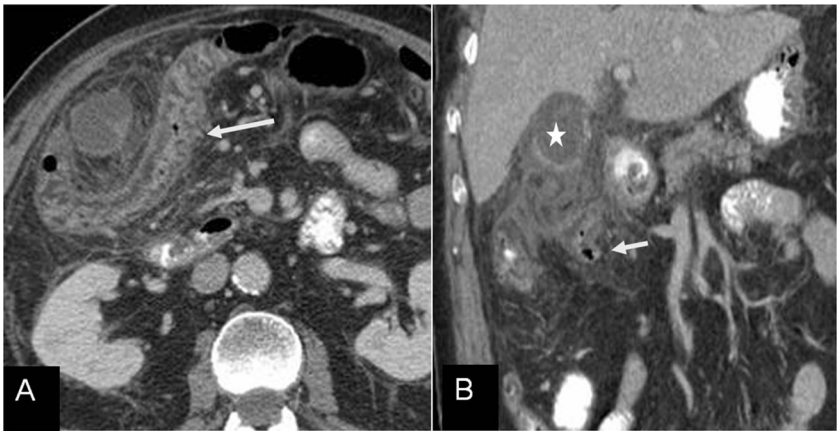

Fig. 5 Postcolonoscopy acute diverticulitis of the hepatic flexure (*white arrows*) presenting 3 days after the procedure in a 62-year-old man. Axial (**a**) and coronal (**b**) contrast-enhanced CT shows colonic wall edema (*long arrow*) with pericolic fat stranding and small irregular diverticulum (*short arrow*). CT picture mimicked acute gangrenous cholecystitis (*asterisk*). Intraoperatively, a perforated diverticulum sealed by the gallbladder was identified

hospital stay, a lower negative appendectomy rate, wound infection, and wound rupture, but higher rates of intestinal injury, postoperative abdominal abscess, and urinary infection [33]. Overall complication rate reported is 8 % and includes surgical site infection (3.4 %), ileus (1.1 %), intra-abdominal abscess (2.6 %), enteritis, bleeding, intestinal adhesions, and stump appendicitis [34]. Emergency CT is recommended in patients with persistent pain and/or fever in the postoperative period with other clinical signs of peritonitis or systemic inflammation.

Postoperative intra-abdominal infections after LA may manifest as variable-sized fluid collections with irregular enhancing wall with or without gas bubbles in the right iliac fossa. Associated retained or dropped appendicoliths, localized peritoneal thickening, free fluid in right paracolic gutter and pelvis, and right pleural effusion can be seen [35] (Fig. 6). Deep-seated abscesses can be seen in the pelvis, subphrenic, perihepatic locations, and rarely in the liver. Stump appendicitis is a unique complication due to residual long stump seen more commonly in LA as compared to OA. Diagnosis is often delayed with increased rate of complications. Imaging features are no different from conventional acute appendicitis and include tubular structure arising from the cecum measuring >6 mm in diameter with wall thickening, enhancement, and fat stranding [36].

Laparoscopic partial nephrectomy

Small renal neoplasms can be treated by laparoscopic partial nephrectomy. Studies reported a major complication rate of 10 % and an overall complication rate of 23 % with this procedure [37]. In a study when compared to open partial nephrectomy, laparoscopic partial nephrectomy resulted in a higher rate of major complications (5 vs. 0 %) [38]. Reported complications include vascular complications, urinary leakage, infection, injury to adjacent viscera, transient renal insufficiency, transient hematuria, ureteral injury, and recurrent tumor.

Vascular complications

Vascular complications are the most common complications and include renal infarction, hemorrhage/hematoma,

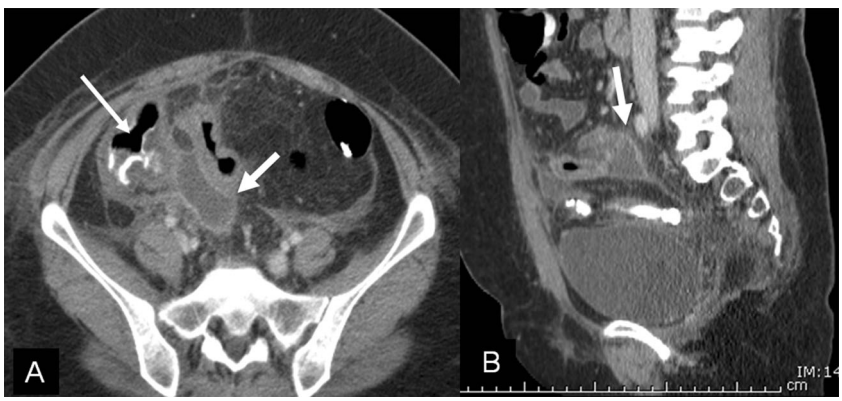

Fig. 6 Postappendectomy abscess in a 50-year-old man, postoperative day 8. **a** Axial and **b** sagittal contrast-enhanced CT shows fluid collection with enhancing wall (*short arrows*) at the appendectomy site, close to contrast-filled cecum (*long arrow*)

pseudoaneurysm, and arteriovenous fistula (AVF) [37]. Vascular complications after laparoscopic nephrectomy are suspected when patients have postoperative pain, hematuria, and proteinuria. Large perinephric hematomas can cause hypertension due to the phenomenon of "page kidney" [39]. Renal infarction is seen on contrast-enhanced CT as peripheral, wedge-shaped, nonenhancing areas in the renal cortex. In cases of complete renal infarction, a rim of enhancement is noted at the periphery of the cortex (rim sign) due to preserved capsular blood flow. Thrombosis of the renal artery is seen as abrupt cutoff of the artery. Perinephric hematoma is seen as high-density fluid in the perinephric space on noncontrast CT. Active contrast extravasation can be seen in cases of ongoing hemorrhage. Pseudoaneurysm is seen as a contrast-filled outpouching along the main or intrarenal arteries [40]. Renal AVF is of the high-flow type and seen on dynamic CT as early opacification of renal veins (Fig. 7) [37].

Treatment of vascular complications of laparoscopic nephrectomy can vary depending on the severity. Renal infarction in the early stages can be managed by thrombolysis or thrombectomy [41]. Perirenal hematomas causing page kidney may need percutaneous drainage or laparoscopic decortication [42]. Renal pseudoaneurysm and AVF are usually treated with endovascular or percutaneous embolization and rarely require surgery [43].

Urinary leak

Injury to the calyces or ureter can result in urinary leakage which can result in a simple fluid collection or a heterogeneous collection filled with blood products. This complication is more frequent with the resection of large endophytic masses. Severe urinary leaks can cause anuria, scrotal swelling, and elevations in serum creatinine levels. Persistent leakage can form urinomas. CT urogram shows leakage of contrast from the collecting system into the surgical bed during the excretory phase (Fig. 8). It resolves spontaneously in most of the cases. Sometimes, it requires the placement of a ureteral stent or nephrostomy catheter. Persistent urinomas require guided percutaneous drainage [44, 45].

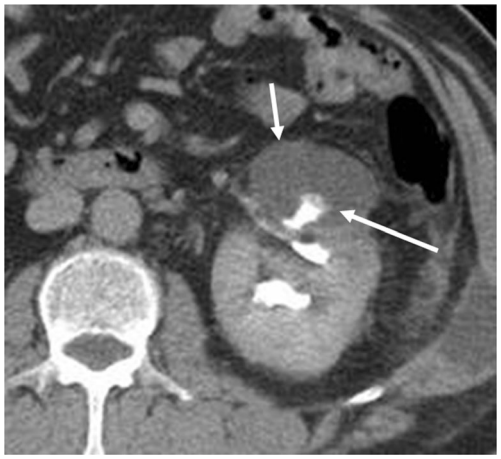

Fig. 8 Laparoscopic partial nephrectomy complicated by urine leak (*long arrow*) and urinoma formation (*short arrow*) in a 35-year-old man demonstrated on a CT urogram

Transurethral resection of the prostate

Transurethral resection of the prostate (TURP) is one of the standard procedures performed in the management of benign prostatic hyperplasia (BPH). The acute complications with TURP are bleeding requiring transfusion (0.4–7.0 %), transurethral resection (TUR) syndrome (development of neurological symptoms due to dilutional hyponatremia, occurring in <1 % of patients), extravasation of urine (4 %), clot retention (2–5 %), urinary retention (3–9 %), and septic shock (2.3 %). Late complications include urethral strictures and bladder neck contractures [46].

Bleeding and urinary retention

Urinary retention is the most common postoperative complication after TURP. It is mainly due to primary detrusor failure [47]. Recurrent bleeding in the postoperative period can result in large obstructive clots causing urinary retention which occurs mostly between 24 h and 2 weeks after the procedure [48]. Suprapubic distension, severe lower abdominal discomfort, vasovagal symptoms, and anuria are the clinical

Fig. 7 Postlaparoscopic partial right nephrectomy for a complex cyst in a 40-year-old man. Coronal (**a**) and axial (**b**) contrast-enhanced CT shows the arteriovenous fistula involving a lower polar arterial branch with a small pseudoaneurysm (*short arrow*) and early opacification of the renal vein (*long arrow*). **c** Catheter angiography confirms the arteriovenous fistula with the pseudoaneurysm (*short arrow*) and early draining renal vein (*long arrow*). Note the urinoma in the surgical bed (*asterisk*, **b**)

manifestations in acute urinary retention. Ultrasound will identify the clots as echogenic material and can also show the residual prostatic tissue. Generous oral fluid intake and bladder irrigation can help flush out the clots [46].

Urine extravasation

During TURP, the capsule of the bladder may be injured or the bladder neck may get divided. This can result in extravasation of the irrigation fluid which is usually extraretroperitoneal and occasionally intraperitoneal. Clinical features include nausea, vomiting, tense abdomen, and lower abdominal and back pain [49]. TUR syndrome is likely with extravasation and these patients can also have restlessness, neurological symptoms, and visual disturbances. Extravasation appears as fluid collection on ultrasonography (USG). CT cystogram demonstrates extravasation of contrast in these patients and differentiates intra- from extraperitoneal leak (Fig. 9) [50]. Intraperitoneal leak is seen as contrast around the bowel loops, between the mesenteric folds and in the paracolic gutters on CT cystography. Localized perivesical hematoma is seen in extraperitoneal leak and can track into fascial planes of the scrotum and upper thigh in severe cases [51]. Treatment of extravasation can vary depending on the severity and location and includes percutaneous drainage, surgical exploration, or conservative management [49, 52].

Urinary catheterization

Inserting a urinary catheter is an essential skill in medicine. The recent data analysis found severe mechanical trauma, symptomatic bacterial infection, anaphylaxis, catheter toxicity, and hypersensitivity as significant complications with urinary catheterization (UC) [53, 54]. There is an increased risk of infection if the catheterization duration exceeds 48 h. Long-term UC may cause pyelonephritis, nephrocystolithiasis, and urethral stricture. Mechanical tissue trauma can be in the form of urethral rupture, bladder perforation, enterovesical fistula, and ureteral catheterization [54].

The two most common complications of UC are urethral trauma and retention of the Foley balloon in the urethra [55]. Urethral rupture can occur with traumatic UC or prior stricture. Patients with urethral rupture can present with pain, hematuria, blood at the meatus, and high riding prostate. Cautious retrograde urethrography can show the contrast extravasation at the site of rupture and underlying stricture if any. Aberrant placement of Foley's balloon occurs in the urethra and rarely in the ureter. Balloon inflation in the urethra is often detected clinically due to severe pain and autonomic dysreflexia and can be confirmed on CT, USG, or by contrast injection through the catheter [56]. Ureteral catheterization though very rare can occur with UC in women, and an empty bladder can increase the risk of ureteral catheterization [57].

Cystography, retrograde urethrography, antegrade urography, ultrasound, and CT are the imaging studies performed to diagnose the type, location, and severity of the complications of UC (Fig. 10). Surgery may be required to repair urethral rupture. Ureteral catheterization and ureteral injury could be prevented by confirming the location of the tip of the catheter by instillation of contrast media through the Foley catheter or by simple aspiration of urine before inflating the balloon [58].

Gynecological procedures

Dilatation and curettage (D&C), hysteroscopy, laparoscopic hysterectomy, laparoscopic myomectomy, and tubal ligation are few of the commonly performed minimally invasive gynecological procedures. Iatrogenic injury to adjacent structures especially the ureters, bladder, and bowel is the most common complications of pelvic laparoscopic procedures [59]. Complications specific to the reproductive organs

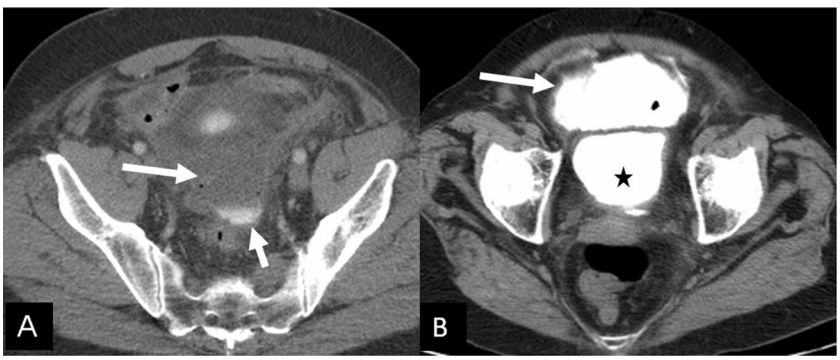

Fig. 9 Urinary bladder rupture following TURP. **a** A 75-year-old man post-TURP. Contrast-enhanced CT with cystogram performed immediately after TURP shows significant fluid in the pelvis with extravasated contrast (*short arrow*) and extraluminal air (*long arrow*) indicating intraperitoneal bladder rupture. **b** A 78-year-old male with urinary bladder rupture following TURP. CT cystogram demonstrates contrast-filled collection (*arrow*) anterior to urinary bladder (*asterisk*) representing extraperitoneal bladder rupture

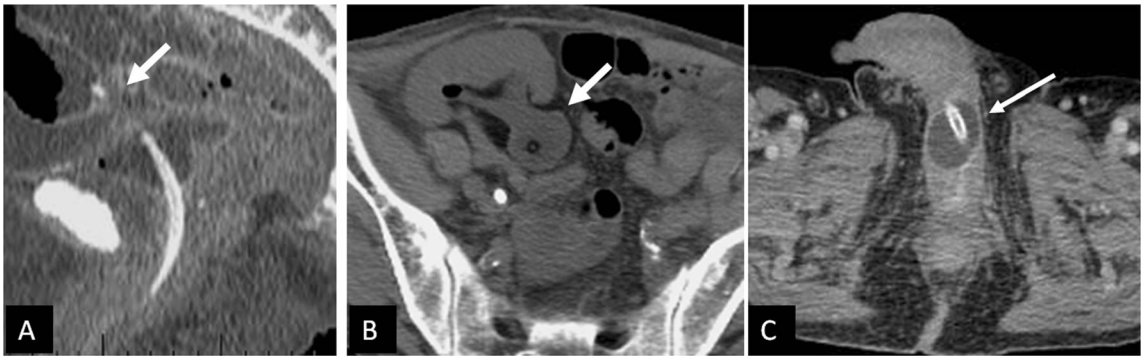

Fig. 10 Complications of urinary catheterization. **a** Sagittal noncontrast CT shows bladder perforation following Foley's catheterization with the tip of the catheter seen in the adjacent bowel loop (*arrow*). **b** Axial noncontrast CT shows the Foley's balloon inflated in the transplant kidney pelvis (*arrow*). **c** Axial contrast-enhanced CT reveals aberrant placement of Foley's balloon in the penile urethra (*arrow*)

include infection, hemorrhage, Asherman's syndrome, uterine perforation, and cervical and vaginal tears [60].

Hemorrhage

Hemorrhage due to vascular injury is one of the common complications of pelvic surgery and curettage ranging from mild to massive seen in 0.05–5 % of abortion procedures. Pseudoaneurysms, acquired arteriovenous malformations (AVMs), and direct vessel ruptures are the different forms of vascular injury. Gray scale sonographic findings are subtle and nonspecific, and transvaginal sonography (TVS) with color and spectral Doppler, the imaging modality of choice, will be required to make the diagnosis. Pseudoaneurysms appear as blood-filled cystic structure with high resistance, high velocity turbulent flow. Tangle of vessels with multidirectional low resistance, high velocity flow producing a color mosaic pattern is seen in acquired AVMS (Fig. 11). Direct vessel rupture is usually an intraoperative diagnosis and rarely made on imaging. Transcatheter arterial embolization is a safe and effective method of treating iatrogenic vascular injuries in the uterus with the advantage of preserving reproductive function [61–64].

Uterine perforation

Sharp curettage used during the procedure may cause uterine perforation, and the most common site is uterine fundus. The incidence of uterine perforation after D&C is 0.16 %, and the risk is more when performed on patients with postpartum hemorrhage, prior scar, and intrauterine adhesions [65, 66]. Patients present with severe lower abdominal or pelvic pain and often vaginal bleeding. Ultrasound is often the initial diagnostic modality used and shows fluid collection or hematoma adjacent to the perforated site and rarely the site of uterine rupture as a hypoechoic or anechoic transmural defect in myometrium extending to the endometrium. On CT, the site of perforation is shown as a hypodense defect with disruption of myometrial continuity and adherent bowel loops in chronic cases [67]. MRI shows the site of perforation more confidently due to its excellent soft tissue contrast [68]. Observation and supportive treatment may be enough to treat cases of

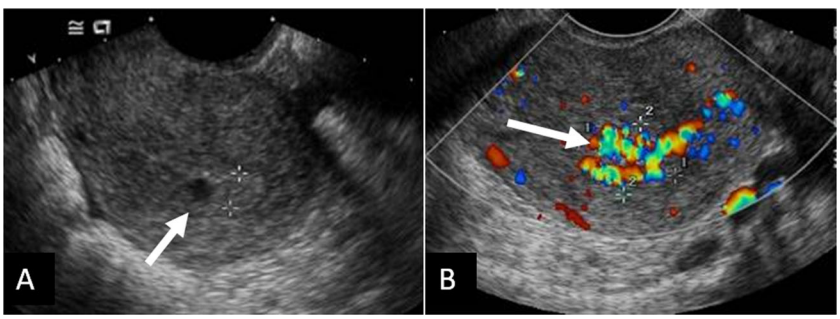

Fig. 11 Twenty-three-year-old female postdilatation and curettage presents with bleeding per vaginum. **a**, **b** Transvaginal ultrasound performed for retained products of conception demonstrates hypoechoic lesion (*arrow*, **a**) at the endomyometrial interface which is highly vascular with multidirectional high velocity flow (*arrow*, **b**) suggestive of arteriovenous fistula

Table 1 Overview of complications of minimally invasive procedure with their key clinical and imaging features

Procedure	Complication	Clinical features	Imaging features
Endoscopic retrograde cholangiopancreatography (ERCP)	Acute pancreatitis	Abdominal pain and elevated amylase	CT—swollen pancreas with peripancreatic stranding and/or collection
	Duodenal perforation	Abdominal pain and often elevated amylase	CT—free retroperitoneal air and duodenal pneumatosis
	Duodenal hemorrhage	Abdominal pain with hematemesis or melena	CT—hyperdense duodenal mass with thickening with or without active extravasation
	Cholangitis	Abdominal pain, fever, and elevated leukocytes	CT—biliary dilatation, pneumobilia, wall thickening, and enhancement
Laparoscopic cholecystectomy (LC)	Biliary injury	Abdominal pain, jaundice, fever, pale stools, and dark urine	CT—collection in GB fossa, biliary dilatation MRCP and ERCP—contrast leak from the site of injury, biliary dilatation, retained stones
	Dropped gallstones	Localized abdominal pain, cutaneous sinus, or bowel obstruction	CT—spilled gallstones with associated abscess and bowel dilatation if adhesions
	Vascular injury	Abdominal pain, jaundice, and hemobilia	CT angiography—vascular pseudoaneurysm and active extravasation
Colonoscopy	Perforation	Abdominal pain, distension, fever, and elevated leukocytes	CT—pneumoperitoneum in close relation to the colon
	Hemorrhage	Bleeding per rectum or melena	CT angiography—active contrast extravasation with hyperdense colonic contents
Laparoscopic appendectomy (LA)	Intraabdominal abscess	Abdominal pain and fever	CT—fluid collection with gas bubbles, retained appendicolith, peritonitis
Laparoscopic nephrectomy	Vascular injury	Flank pain, hematuria, and proteinuria	CT angiography—pseudoaneurysm, arteriovenous fistula, renal infarction, renal artery or venous thrombosis, perinephric hematoma
	Urine leak	Anuria, abdominal pain, and elevated serum creatinine	CT urography—contrast extravasation from pelvicaliceal system
Transurethral resection of prostate (TURP)	Bleeding	Suprapubic pain and distension with anuria	CT and USG—luminal blood clots with overdistended bladder
	Urine extravasation	Lower abdominal pain, tense abdomen, and anuria	CT cystogram—contrast extravasation from bladder into intra- or extraperitoneal compartment
Urinary catheterization (UC)	Urethral and bladder rupture	Suprapubic pain, hematuria, and high riding prostate	Contrast extravasation in CT cystogram or urethrogram
	Aberrant placement of Foley's balloon	Severe pain and autonomic dysreflexia	CT and USG—abnormal position of Foley's balloon in urethra, bladder neck, ureter, or extravesical location
Gynecological procedures	Arteriovenous malformations	Abnormal vaginal bleeding	USG—tangle of vessels with multidirectional high velocity flow
	Uterine perforation	Severe lower abdominal pain and vaginal bleeding	USG, CT, and MRI—complete or incomplete defect in the uterine wall

CT computed tomography, *USG* ultrasonography, *MRI* magnetic resonance imaging, *MRCP* magnetic resonance cholangiopancreatography, *ERCP* endoscopic retrograde cholangiopancreatography

uterine perforation except in some cases which will need explorative laparotomy.

Conclusion

Minimally invasive procedures are not without complications. Clinical features are crucial in suspecting these complications. Imaging plays an important role in differentiating these complications and guiding appropriate management. A summary of key clinical and imaging features of the complications are provided in Table 1. Knowledge of the imaging findings of these complications is essential for the radiologists to recognize them promptly and thereby helping the physicians to deliver the appropriate treatment.

Conflict of interest The authors declare that they have no conflict of interest.

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