Internal Hernias in the Era of Multidetector CT: Correlation of Imaging and Surgical Findings[1]

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Abbreviations: MPR = multiplanar reformation, 3D = three-dimensional

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SA-CME LEARNING OBJECTIVES

After completing this journal-based SA-CME activity, participants will be able to:

- Describe the diagnostic approach to internal hernias with use of multidetector CT.
- Identify key vessels in the various types of internal hernias seen at multidetector CT.
- Discuss the imaging features of various types of internal hernias.

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Clinical diagnosis of internal hernias is challenging because of their nonspecific signs and symptoms. Many types of internal hernias have been defined: paraduodenal, small bowel mesentery–related, greater omentum–related, lesser sac, transverse mesocolon–related, pericecal, sigmoid mesocolon–related, falciform ligament, pelvic internal, and Roux-en-Y anastomosis–related. An internal hernia is a surgical emergency that can develop into intestinal strangulation and ischemia. Accurate preoperative diagnosis is crucial for appropriate management. Multidetector computed tomography (CT), with its thin-section axial images, high-quality multiplanar reformations, and three-dimensional images, currently plays an essential role in preoperative diagnosis of internal hernias. The diagnostic approach to internal hernias at multidetector CT includes detecting an intestinal closed loop, identifying the hernia orifice, and analyzing abnormal displacement of surrounding structures and key vessels around the hernia orifice and hernia sac. At each step, multidetector CT can depict pathognomonic findings. A saclike appearance suggests an intestinal closed loop in several types of internal hernias. Convergence, engorgement, and twisting of mesenteric vessels in the hernia orifice can be seen clearly at multidetector CT, especially with use of multiplanar reformations. For definitive diagnosis of an internal hernia, analysis of displacement of anatomic landmarks around the hernia orifice is particularly important, and thin-section images provide the required information. Detailed knowledge of the anatomy, etiology, and imaging landmarks of the various hernia types is also necessary. Familiarity with the appearances of internal hernias at multidetector CT allows accurate and specific preoperative diagnosis.

Introduction

Meyers et al (1) have defined an *internal hernia* as a protrusion of abdominal viscera through an opening within the confines of the peritoneal cavity, although not all internal hernias are strictly intraperitoneal. Orifices of internal hernias can be congenital or acquired. Congenital orifices include a normal foramen or unusual peritoneal fossae or recesses related to failure of peritoneal fusion, whereas acquired orifices result from trauma, inflammation, or previous surgery. In most cases, the herniated viscera are small bowel loops. Internal hernia is classically reported to cause approximately 4% of cases of acute small bowel obstruction (2).

Clinical signs and symptoms of internal hernia are nonspecific and overlap with those of other pathologic conditions in the abdomen. The most common clinical symptoms are nausea, vomiting, abdominal pain, and abdominal distention (3). Patients present with a wide spectrum of symptoms, ranging from no symptoms to symptoms of acute small bowel obstruction. Internal hernias occasionally show

TEACHING POINTS

- Today, multidetector CT is the first-line imaging technique for internal hernia. Thin-section axial images and high-quality multiplanar reformations (MPRs) allow improved visualization of normal anatomic structures and pathologic conditions, leading to greater diagnostic accuracy. Furthermore, three-dimensional (3D) images such as volume-rendered images aid in the understanding of pathologic conditions and contribute to optimal surgical planning.
- Internal hernias are divided into three categories on the basis of the type of hernia orifice: *(a)* normal foramen, *(b)* unusual peritoneal fossa or recess into the retroperitoneum, and *(c)* abnormal opening in a mesentery or peritoneal ligament.
- Most mesenteries and peritoneal ligaments consist of two peritoneal layers. Abnormal openings can arise in only one peritoneal layer or through both layers. Internal hernias associated with an abnormal opening in a mesentery or peritoneal ligament are subcategorized according to the degree of the defect: *(a)* transmesenteric or fenestra type, if both peritoneal layers are involved; or *(b)* intramesenteric or pouch type, if either peritoneal layer is involved.
- A saclike appearance strongly supports a diagnosis of internal hernia. Unfortunately, this sign is not observed in all types of internal hernias. A saclike appearance can be observed with internal hernias into an unusual fossa in the retroperitoneum or with intramesenteric-type internal hernias.
- Definitive diagnosis of internal hernias requires identification of abnormal displacement of surrounding structures and key vessels around the hernia orifice and hernia sac. Detailed knowledge of landmarks in the various types of internal hernias is the key to diagnosis.

spontaneous reduction, resulting in intermittent symptoms. For these reasons, precise clinical diagnosis of internal hernias is difficult.

Multidetector computed tomography (CT) has established its status as a powerful diagnostic tool for acute abdomen, and this remains true for internal hernias. Although an increasing number of pathognomonic CT findings of internal hernia have been reported, the majority of such reports are individual case reports. Small numbers of review articles (4–8) and scientific studies (9–13) have been published.

This article provides an overview of the diagnostic approach to internal hernias with use of multidetector CT, with emphasis on tracing key vessels. In addition, various pathognomonic findings for the various types of internal hernias at multidetector CT are presented. The usefulness of multidetector CT is also discussed, with correlation of imaging and intraoperative findings.

Classification

The classification devised by Ghahremani and Meyers (14) is relatively well accepted (4). In this classification, internal hernias are classified as follows: paraduodenal, foramen of Winslow, intersigmoid, pericecal, pelvic and supravesical, transmesenteric, and transomental. However, this classification is neither fully systematic nor comprehensive. A modified classification and nomenclature is shown in Figure 1. Usually, hernia types are named according to the location of the hernia orifice. The exceptions are lesser sac, pelvic internal, and Roux-en-Y anastomosis–related hernias, which can involve various hernia orifices.

Internal hernias are divided into three categories on the basis of the type of hernia orifice (Table 1): *(a)* normal foramen, *(b)* unusual peritoneal fossa or recess into the retroperitoneum, and *(c)* abnormal opening in a mesentery or peritoneal ligament. This categorization is important for a systematic radiologic approach to diagnosis.

Most mesenteries and peritoneal ligaments consist of two peritoneal layers. Abnormal openings can arise in only one peritoneal layer or through both layers. Internal hernias associated with an abnormal opening in a mesentery or peritoneal ligament are subcategorized according to the degree of the defect (Fig 2): *(a)* transmesenteric or fenestra type, if both peritoneal layers are involved; or *(b)* intramesenteric or pouch type, if either peritoneal layer is involved.

Classically, paraduodenal hernia has been reported as the most common type of internal hernia (1). However, reports of postoperative internal hernias, particularly after Roux-en-Y anastomosis reconstruction, have been increasing recently (6,9). Transmesenteric hernia is currently the most prevalent type, even if Roux-en-Y anastomosis–related hernia is excluded (15). Current incidences of the various hernia types are thus difficult to ascertain.

Multidetector CT Technique

Internal hernia is a challenging disorder for clinicians to diagnose because of the nonspecific signs and symptoms. Clinical use of CT enables inspection of the inside of the abdomen and facilitates use of advanced diagnostic procedures (16). However, definitive diagnosis remained difficult in the era before multidetector CT.

Today, multidetector CT is the first-line imaging technique for internal hernias. Thin-section axial images and high-quality multiplanar reformations (MPRs) allow improved visualization of normal anatomic structures and pathologic conditions, leading to greater diagnostic accuracy. Furthermore, three-dimensional (3D) images such as volume-rendered images aid in the understanding of pathologic conditions and contribute to optimal surgical planning.

Use of intravenous contrast material is desirable, unless contraindicated, to rule out other causes of small bowel obstruction. Contrast enhancement also allows evaluation of blood

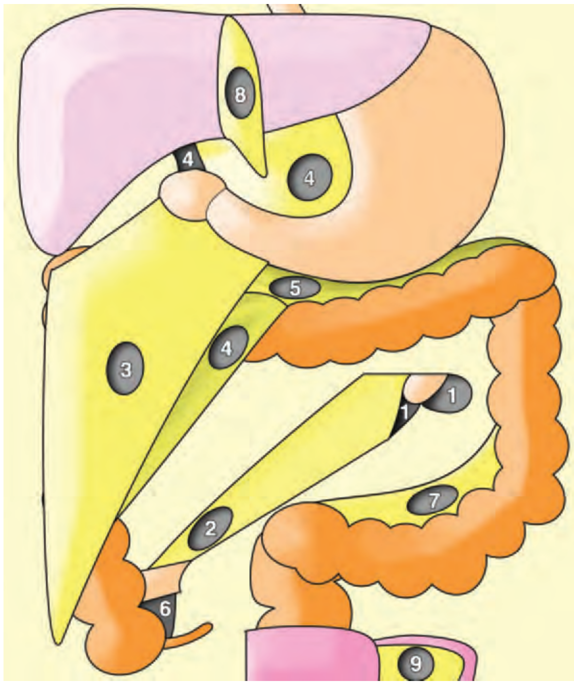


Figure 1. Drawing shows the anatomic sites of internal hernias: *1* = paraduodenal hernia, *2* = small bowel mesentery–related hernia, *3* = greater omentum–related hernia, *4* = lesser sac hernia, *5* = transverse mesocolon–related hernia, *6* = pericecal hernia, *7* = sigmoid mesocolon–related hernia, *8* = falciform ligament hernia, *9* = pelvic internal hernia. (Roux-en-Y anastomosis–related hernia is not shown.)

Table 1: Categorization of Internal Hernias According to Type of Hernia Orifice

Type of Hernia Orifice	Hernia Category
Normal foramen	Foramen of Winslow hernia (type of lesser sac hernia)
Unusual peritoneal fossa or recess into retroperitoneum	Paraduodenal hernia
	Pericecal hernia
	Intersigmoid hernia (subtype of sigmoid mesocolon–related hernia)
	Most types of pelvic internal hernia (except for broad ligament hernia)
Abnormal opening in a mesentery or peritoneal ligament	Small bowel mesentery–related hernia
	Greater omentum–related hernia
	Most types of lesser sac hernia (except for foramen of Winslow hernia)
	Transverse mesocolon–related hernia
	Transmesosigmoid and intramesosigmoid hernia (subtypes of sigmoid mesocolon–related hernia)
	Falciform ligament hernia
	Broad ligament hernia (type of pelvic internal hernia)
	Roux-en-Y anastomosis–related hernia

flow to the herniated intestine and assessment of the severity of small bowel strangulation (17). Furthermore, intravenous contrast-enhanced CT depicts mesenteric vessels passing through or into the hernia orifice and landmark vessels of the surrounding structures, which contributes to definitive diagnosis of internal hernias and identification of their type.

Nonenhanced CT scans should be used to detect hyperattenuating bowel wall reflecting hemorrhagic congestion and to compare the degree of enhancement after administration of intravenous contrast material (17). Portal venous phase scans are considered to be the most important, with the advantages of depicting mesenteric vessels and allowing better assessment of abnormalities of the bowel wall itself, although acquisition of arterial phase images and reformations of CT angiograms are also of great value in assessment of mesenteric arteries (18).

Use of oral contrast material is controversial. Administration of water-soluble contrast material is not only helpful for identification of the site and degree of obstruction but also is therapeutic, particularly in patients with an adhesive small bowel obstruction (19,20). However, administration of oral contrast material is accompanied by patient discomfort and risk for aspiration in

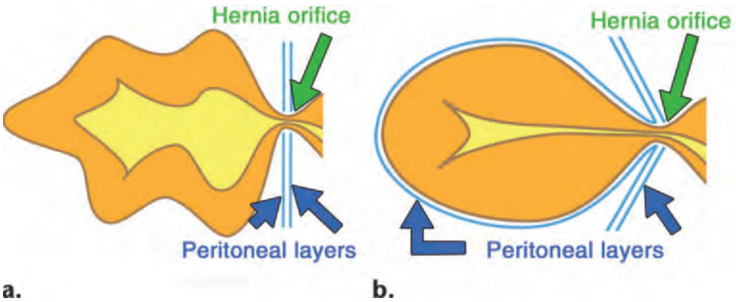


Figure 2. Internal hernias associated with an abnormal opening in a mesentery or peritoneal ligament. Drawings show the transmesenteric or fenestra type **(a)**, in which a defect arises through two peritoneal layers, and the intramesenteric or pouch type **(b)**, in which a defect arises in only one peritoneal layer.

patients with a high-grade obstruction. In addition, the low-attenuation fluid and gas within the obstructed lumen provide excellent contrast relative to the normally enhancing bowel wall at contrast-enhanced CT, and this is obscured by the presence of high-attenuation intraluminal contrast material (21). Therefore, routine administration of oral contrast material before CT is considered unnecessary (8,21,22).

Multidetector CT scanning protocols differed slightly among the cases described in this article because CT images were collected from multiple institutions. As an example, the parameters of a 64-row multidetector CT scanner (Lightspeed VCT; GE Healthcare, Milwaukee, Wis) were as follows: tube voltage, 120 kVp; noise index, 9.88 HU at 5-mm section collimation; tube current, variable; detector configuration, 64 row-detectors with a 0.625-mm section thickness; beam collimation, 40 mm; rotation time, 0.5 seconds; pitch, 0.988; display field of view, 32 cm; and reconstruction algorithm, adaptive statistical iterative reconstruction (Asir; GE Healthcare) of 30%. The area scanned ranged from the dome of the diaphragm to the ischial tuberosities. After nonenhanced CT images were obtained, multiphasic contrast-enhanced CT was performed unless contraindicated. Nonionic iodinated contrast material that contained 300–370 mg of iodine per milliliter in a dose of 600 mg of iodine per kilogram of body weight was intravenously injected at a rate of 2–5 mL/sec. Multiphasic contrast-enhanced scans included the arterial, portal venous and, if necessary, delayed phases. By using a bolus-tracking program, arterial phase scanning was started automatically 20 seconds after the trigger threshold (150 HU above the baseline) was reached at the level of the supraceliac abdominal aorta. The portal venous and delayed phases were started automatically at 70 and 180 seconds, respectively, after the start of injection. Neither oral nor rectal contrast material was administered in any patients. Reconstructed axial images (section thickness of 5 mm, interval of 5 mm) and coronal MPR images (section thickness of 3 mm, interval of 3 mm) were obtained routinely. In some cases, thin-section axial images, additional MPR images, and 3D images were obtained.

Diagnostic Approach with Multidetector CT

Step 1: Detect an Intestinal Closed Loop

The most crucial condition in internal hernias is mechanical small bowel obstruction. Small bowel obstruction of the internal hernia is usually a closed-loop obstruction, in which a segment of the bowel is occluded at two adjacent points. A direct sign of a closed loop at CT is a U- or C-shaped, fluid-filled, distended intestinal loop, with radial distribution of stretched and thickened mesenteric vessels toward the point of the obstruction (23).

An extremely helpful imaging sign of closed-loop intestine in an internal hernia is a saclike appearance. This is defined as a sacculation and crowding of small bowel loops owing to encapsulation within the hernia sac (1). A saclike appearance strongly supports a diagnosis of internal hernia (16). Unfortunately, this sign is not observed in all types of internal hernias. A saclike appearance can be observed only in cases of internal hernia into an unusual fossa in the retroperitoneum or intramesenteric-type internal hernia (Fig 3).

Closed-loop obstruction is an emergent condition because it can easily develop into intestinal strangulation and ischemia. At this step, the presence and severity of intestinal strangulation should be assessed (17,23).

Step 2: Identify the Hernia Orifice

The convergence of bowel, mesenteric fat, and vessels of the closed loop offers a direct sign of the hernia orifice. MPR CT images are useful for recognizing the convergence of these structures. Engorgement and twisting of mesenteric vessels in the hernia orifice may be observed and are also useful to detect the hernia orifice. However, these signs reflect intestinal strangulation and are not pathognomonic for internal hernia (23). Identifying the

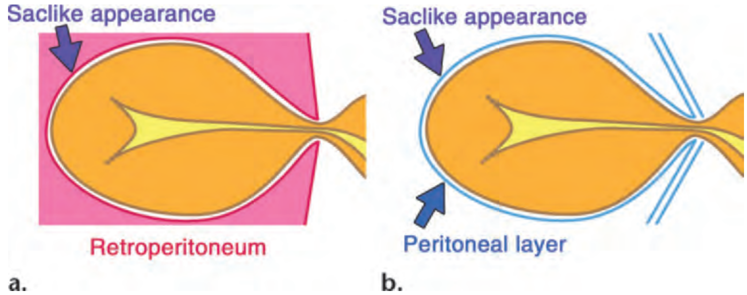


Figure 3. Internal hernias that manifest with a saclike appearance. Drawings show an internal hernia into an unusual fossa or recess in the retroperitoneum **(a)** and an intramesenteric or pouch-type internal hernia **(b)**.

Table 2: Landmark Vessels for Various Mesenteries and Peritoneal Ligaments

Mesentery or Peritoneal Ligament	Landmark Vessels
Gastrohepatic ligament	Left gastric artery and vein, right gastric artery and vein
Hepatoduodenal ligament	Hepatic artery, portal vein, bile duct
Greater omentum	Omental branches of the left and right gastro-omental arteries and veins
Falciform ligament of the liver	Obliterated umbilical vein (round ligament), falciform artery, paraumbilical vein
Small bowel mesentery	Superior mesenteric artery, superior mesenteric vein
Ascending mesocolon	Right colic artery and vein, ileocolic artery and vein
Transverse mesocolon	Middle colic artery and vein
Descending mesocolon	Inferior mesenteric vein, left colic artery and vein
Sigmoid mesocolon	Sigmoid arteries and veins, rectosigmoid vein, superior rectal artery and vein
Broad ligaments of the uterus	Tubal and ovarian branches of the ovarian and uterine arteries and veins

hernia orifice is mandatory because surgical repair is required to prevent recurrence.

Step 3: Analyze Displacement of Surrounding Structures and Key Vessels

Definitive diagnosis of internal hernias requires identification of abnormal displacement of surrounding structures and key vessels around the hernia orifice and hernia sac. Detailed knowledge of landmarks for the various types of internal hernias is the key to diagnosis.

Even multidetector CT cannot depict mesenteries and peritoneal ligaments unless they are outlined by ascites. However, by tracing vessels thoroughly, the radiologist can approximate the locations of mesenteries and peritoneal ligaments (Table 2). Knowledge of the vessels running in the various mesenteries and peritoneal ligaments can thus help identify the key vessels of internal hernias.

Surgical Repair

The first step in surgical treatment is reduction. After reduction has been achieved, the hernia contents are carefully inspected for signs of ischemia, and nonviable structures are subsequently resected (24). The hernia orifice is usually closed to prevent recurrence. Sometimes transection of a surrounding structure from the orifice to the free border is performed, if no vital organ is inside. Closure of the foramen of Winslow is not routine because complications such as portal venous thrombosis may occur (25).

Internal hernias have traditionally been managed with open laparotomy. Recently, laparoscopic surgery in selected patients with internal hernia has shown advantages, including a shorter hospital stay, better cosmetic appearance, and fewer postoperative complications compared with traditional open laparotomy (26).

Paraduodenal Hernia

Paraduodenal hernias are entrapments of the small intestine into a congenital paraduodenal fossa. Although several fossae are reported in this area, two are of particular importance as causes of paraduodenal hernia (27): *(a)* the paraduodenal fossa of Landzert, the causative fossa of left paraduodenal hernia; and *(b)* the mesentericoparietal fossa of Waldeyer, the causative fossa of right paraduodenal hernia (Fig 4). Left paraduodenal hernias are approximately three times more common than right paraduodenal hernias (1,28,29).

Left Paraduodenal Hernia

Left paraduodenal hernias are entrapments of the small intestine into the fossa of Landzert, an unusual congenital peritoneal fossa behind the descending mesocolon (29). This fossa results from failure of part of the descending mesocolon to fuse with the posterior parietal peritoneum (27).

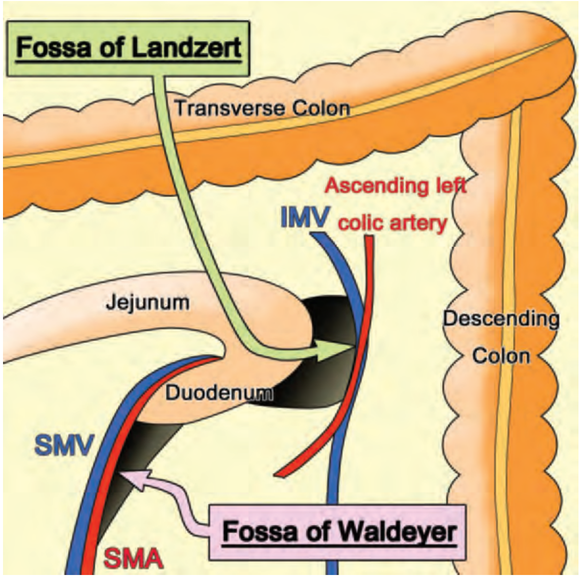
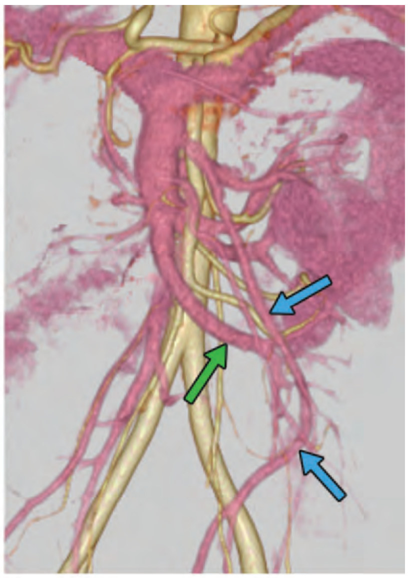


Figure 4. Fossa of Landzert and fossa of Waldeyer. The inferior mesenteric vein *(IMV)* and ascending left colic artery run along the anteromedial border of the fossa of Landzert. The superior mesenteric artery *(SMA)* and superior mesenteric vein *(SMV)* run along the anteromedial border of the fossa of Waldeyer.

Figure 5. Left paraduodenal hernia in a 35-year-old woman who presented with left lower abdominal pain. **(a)** Axial contrast-enhanced CT image shows entrapped intestine within a sac (arrowheads) in the left anterior pararenal space. The inferior mesenteric vein (arrow) is seen at the anteromedial border of the hernia sac. **(b)** Portal venous phase 3D CT angiogram shows mesenteric vessels in the hernia orifice (green arrow) running behind the inferior mesenteric vein (blue arrows). Surgery confirmed entrapment of the jejunum in a fist-sized sac to the left of the ligament of Treitz (not shown). (Case courtesy of Sakae Nagaoka, MD, Japanese Red Cross Medical Center, Tokyo, Japan.)

a.



b.

The fossa of Landzert is reported to be present in approximately 2% of autopsy cases (1).

At multidetector CT, a cluster of intestinal loops with a saclike appearance is observed in the left anterior pararenal space. The inferior mesenteric vein and ascending left colic artery are landmarks situated at the anteromedial edge of the fossa of Landzert. Among these anatomic landmarks, recognition of the inferior mesenteric vein is both easy and important. With a left paraduodenal hernia, the inferior mesenteric vein is observed anterior and medial to the hernia orifice and entrapped intestine. Three-dimensional CT angiography of the portal venous system is also useful to understand the stereographic relationship between the inferior mesenteric vein and the hernia orifice (Fig 5). Asymptomatic cases of left paraduodenal hernia are sometimes encountered (Fig 6).

Right Paraduodenal Hernia

Right paraduodenal hernias usually involve the fossa of Waldeyer. This fossa results from failure of part of the ascending mesocolon to fuse with the posterior parietal peritoneum (27). Right paraduodenal hernia occurs most frequently in the setting of a nonrotated small intestine.

A saclike appearance is seen at multidetector CT. The fossa of Waldeyer is located inferior to the third portion of the duodenum, just behind the root of the small bowel mesentery. The superior

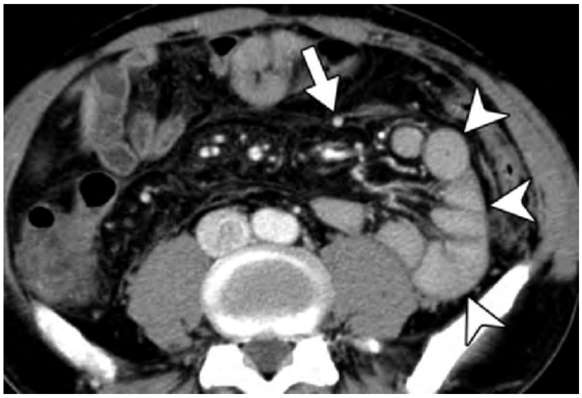
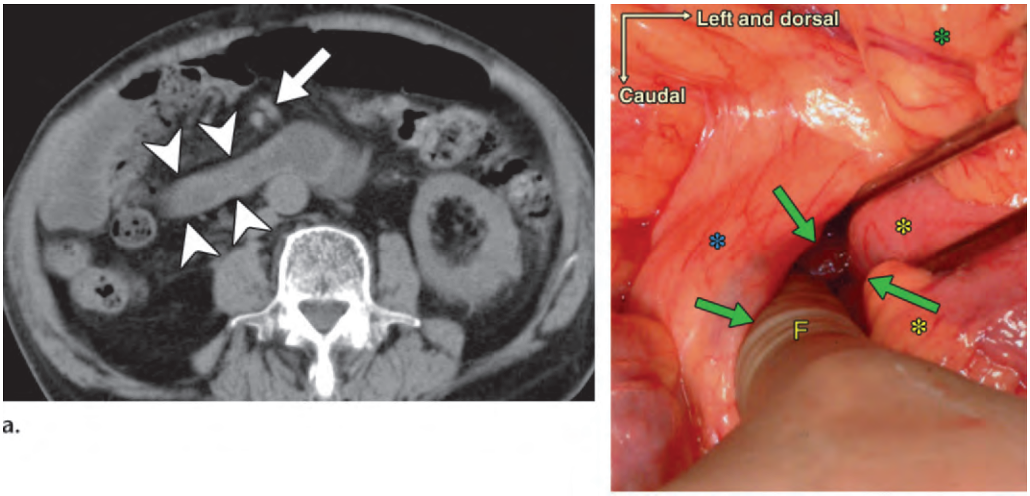


Figure 6. Incidentally diagnosed left paraduodenal hernia in a 54-year-old man with no symptoms. Axial contrast-enhanced CT image obtained for examination of liver cirrhosis shows a saclike mass (arrowheads) posterior to and left of the inferior mesenteric vein (arrow). Surgery was not performed.

Figure 7. Right paraduodenal hernia in an 87-year-old man with a 1-day history of abdominal distention. **(a)** Axial nonenhanced CT image shows the proximal jejunum (arrowheads) posterolateral to the superior mesenteric artery and superior mesenteric vein (arrow). **(b)** Intraoperative photograph (left anterolateral view) after reduction shows the fossa of Waldeyer (arrows) just behind the root of the small bowel mesentery (blue ∗) and in front of the posterior parietal peritoneum (yellow ∗). The hernia orifice was closed with sutures. *F* = surgeon's finger, green ∗ = transverse mesocolon. (Case courtesy of Shinpei Ishikawa, MD, Perfect Liberty Hospital, Tondabayashi, Japan.)



a. b.

mesenteric artery and superior mesenteric vein thus run along the anteromedial free edge of the fossa and offer helpful landmarks for the hernia orifice at multidetector CT (Fig 7). In addition, because the fossa of Waldeyer extends rightward and downward into the ascending mesocolon, the right colic vein is displaced anteriorly by the entrapped intestine (29). In cases of intestinal nonrotation, the superior mesenteric vein exists more left and ventral than usual in relation to the superior mesenteric artery, and the normal third portion of the duodenum is not observed (22,28,29).

Small Bowel Mesentery–related Hernia

Small bowel mesentery–related hernias are herniations through or into an abnormal defect in the small bowel mesentery. Anatomically, the small bowel mesentery connects the jejunum and ileum to the posterior parietal peritoneum and extends from the ligament of Treitz to the ileocecal junction, containing the superior mesenteric artery, superior mesenteric vein, and their branches (30). Mesenteric defects usually arise near the terminal ileum or the ligament of Treitz (1). Two subtypes of small bowel mesentery–related hernias exist: *(a)* transmesenteric hernia, in which both peritoneal layers are affected; and *(b)* intramesenteric hernia, in which either one of the two peritoneal layers is affected.

The overwhelmingly predominant subtype is transmesenteric hernia. At imaging, this subtype shows neither a saclike appearance nor any useful key vessels. In addition, transmesenteric hernias tend to be complicated by volvulus. Distinguishing small bowel obstruction with a transmesenteric hernia from small bowel obstruction from other causes, especially adhesive band and volvulus, is difficult (4,10). Reportedly useful

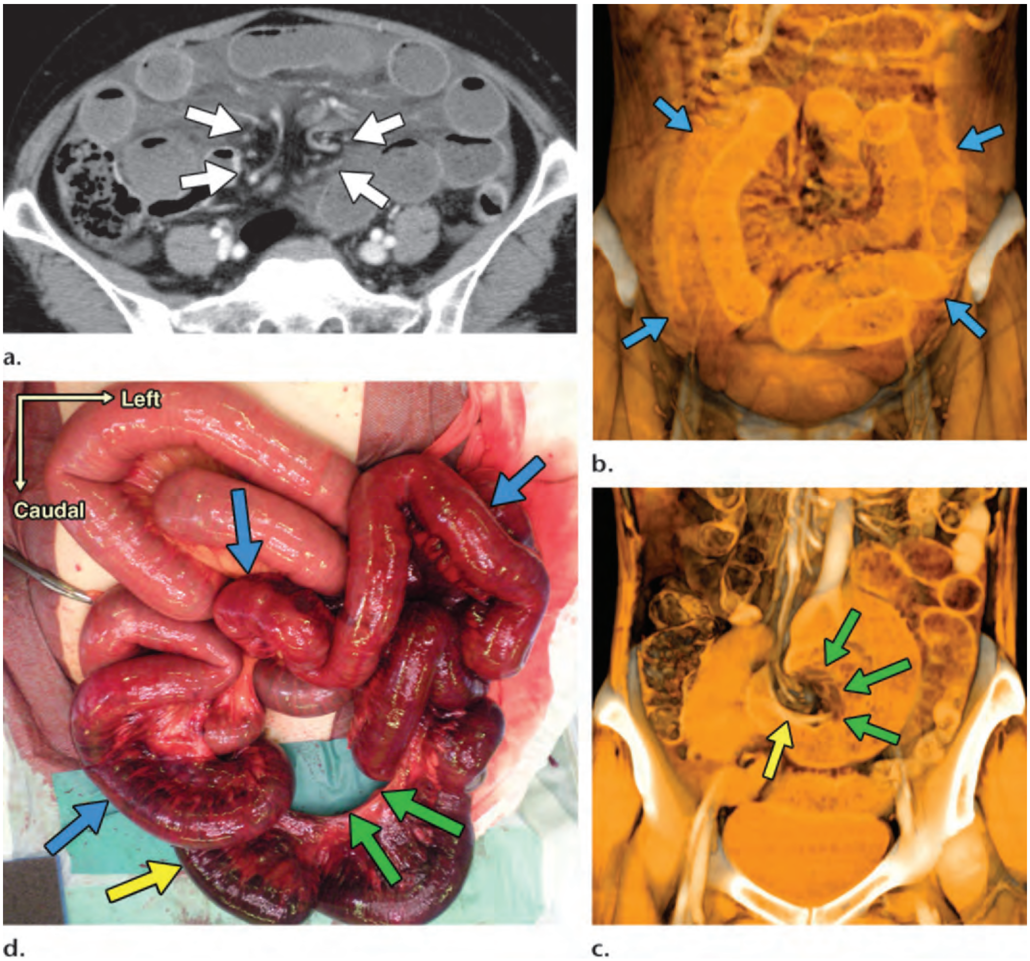


Figure 8. Transmesenteric hernia in a 59-year-old woman with right lower abdominal pain. **(a)** Axial contrast-enhanced CT image shows radial distribution of converging, engorged, twisting mesenteric vessels (arrows). No sac is observed. **(b, c)** Volume-rendered CT images show incarcerated intestine (blue arrows in **b**) in the ventral portion of the peritoneal cavity. Converging mesenteric vessels pass through a defect (green arrows in **c**) in the mesentery of the terminal ileum (yellow arrow in **c**). **(d)** Intraoperative photograph (anterior view) shows incarcerated intestine (blue arrows) through a 19-cm-diameter defect (green arrows) in the mesentery of the terminal ileum (yellow arrow). Approximately 190 cm of gangrenous small intestine was resected, and the defect was closed with sutures. (Fig 8a–8c courtesy of Sakae Nagaoka, MD, Japanese Red Cross Medical Center, Tokyo, Japan, and Chikara Shirata, MD, Graduate School of Medicine, University of Tokyo, Tokyo, Japan. Fig 8d adapted and reprinted, with permission, from reference 31.)

CT findings of transmesenteric hernia include a clustering of small bowel loops and mesenteric vessel abnormalities, such as crowding, stretching, and engorgement, as well as displacement of the main mesenteric trunk to the right (10). An understanding of the relationship between a defect in the small bowel mesentery and incarcerated intestine is somewhat possible with use of 3D images (Fig 8).

Intramesenteric hernias, also called mesenteric pouch hernias, are far less frequent. This subtype is predominantly reported in children. Reported CT findings include a cluster of small bowel encapsulated within a hernia sac and displacement of the superior mesenteric artery and superior mesenteric vein (32).

Only one case each of a transmesenteric hernia through a defect in the mesentery of the appendix and through the mesentery of a Meckel diverticulum has been reported (33,34).

Greater Omentum–related Hernia

Greater omentum–related hernias are herniations through or into an abnormal defect in the greater omentum. Anatomically, the greater omentum hangs down from the greater curvature of the stomach and the proximal part of the duodenum, covering the small intestine like an apron and attaching to the superior aspect of the transverse mesocolon (35,36). This omentum comprises two leaves, each consisting of two peritoneal layers. In adults, the anterior and posterior leaves usually adhere to each other. Causative defects of herniation tend to arise on the right or left side of the omentum (37,38).

In most cases, the herniated intestine passes through both leaves (ie, four peritoneal layers).

Figure 9. Transomental hernia in a 51-year-old man with gradually increasing abdominal pain. Axial contrast-enhanced CT image shows fluid-filled closed-loop intestine (arrowheads) and converging mesenteric vessels and fat in the hernia orifice (black arrows). Omental vessels (white arrows) running vertically are also seen near the incarcerated intestine and the hernia orifice. Surgery confirmed a transomental hernia. (Adapted and reprinted, with permission, from reference 40.)

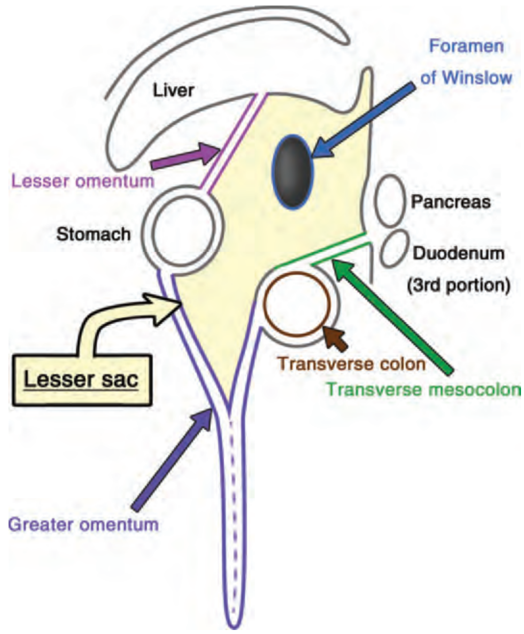


Figure 10. Sagittal diagram (left lateral view) of the structures around the lesser sac. The foramen of Winslow, lesser omentum, greater omentum, and transverse mesocolon are potential orifices for lesser sac hernias. The transverse colon is located posterosuperior to the greater omentum and anteroinferior to the transverse mesocolon.

Transomental hernia usually refers to this subtype. Multidetector CT findings of a transomental hernia are often identical to those of a transmesenteric hernia. However, a closed-loop intestine without a saclike appearance, located in the most anterior portion of the peritoneal cavity, is a characteristic feature because the direction of a transomental hernia is usually posterior to anterior. Omental branches of the left and right gastroomental vessels are landmarks that run inside the apronlike greater omentum. Therefore, once the hernia orifice is detected, omental vessels that run vertically around the hernia orifice contribute to the diagnosis of transomental hernia at multidetector CT (39) (Fig 9).

Lesser Sac Hernia

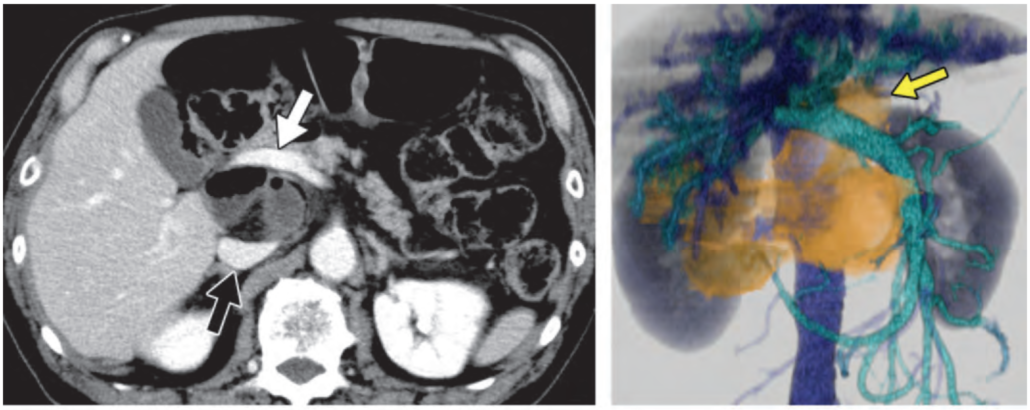
The lesser sac is a unique remnant of the primitive right peritoneal space and is due to the rotation of the viscera in the upper abdomen during fetal development. The only communication with the remainder of the peritoneal cavity is the foramen of Winslow. The organs surrounding the lesser sac are the spleen on the left, the stomach anteriorly, the proximal part of the duodenum on the right, the transverse colon inferiorly, and the pancreas posteriorly (35,41). Although several peritoneal ligaments connect these organs, the lesser omentum, greater omentum, and transverse mesocolon are important sites of hernia orifices (Fig 10).

Lesser sac hernias include several types that are classified according to the hernia orifice (42). Identification of the hernia orifice and hernia type is required before surgery. At multidetector CT, intestinal loops are usually observed in the lesser sac, with the stomach displaced anteriorly, except in the case of a combined lesser sac hernia.

Foramen of Winslow Hernia

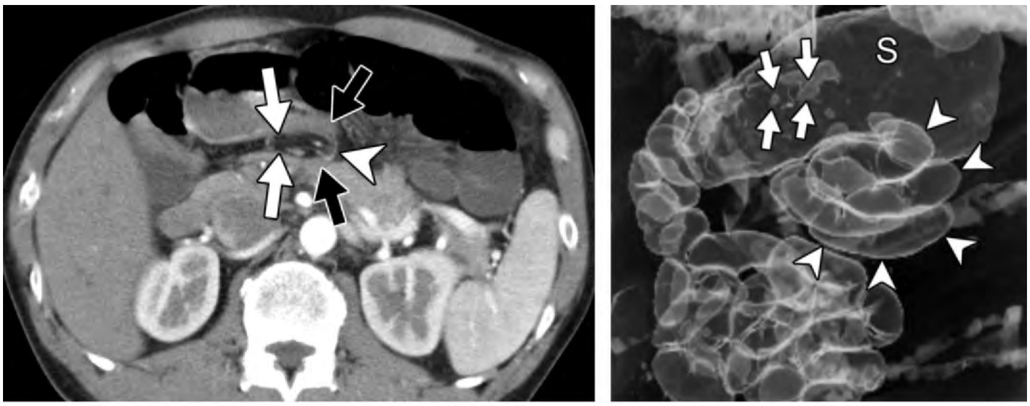
Foramen of Winslow hernias are herniations in which the viscera enter the lesser sac through the epiploic foramen of Winslow. They are the most common type of lesser sac hernia (36). This type is congenital because the foramen of Winslow is a normal anatomic structure. The most commonly involved viscus is the small bowel, but the terminal ileum, cecum, ascending colon, transverse colon, and gallbladder can also be involved (43).

The foramen of Winslow is located inferior to the caudate lobe of the liver, anterior to the inferior vena cava, superior to the second portion of the duodenum, and posterior to the hepatoduodenal ligament that contains the hepatic artery, portal vein, and bile duct (30,44). The presence of herniated viscera in the lesser sac, in a "beak" shape pointing toward the foramen of Winslow, is observed at multidetector CT. When the small or



a. b.

Figure 11. Foramen of Winslow hernia in a 74-year-old man with intermittent abdominal pain. **(a)** Axial contrast-enhanced CT image shows mesenteric vessels and a cluster of intestine between the inferior vena cava (black arrow) and portal vein (white arrow). **(b)** Volume-rendered CT image of the intestine (orange), venous system (dark blue), and portal venous system (light blue) shows a short segment of intestine in the superior recess of the lesser sac (arrow) through the foramen of Winslow. The herniation was spontaneously reduced after placement of a long nasointestinal tube. (Case courtesy of Shigeru Furui, MD, and Asako Yamamoto, MD, Teikyo University School of Medicine, Tokyo, Japan.)



a. b.

Figure 12. Lesser sac hernia through the lesser omentum in a 44-year-old man who presented with acute abdominal pain. **(a)** Axial contrast-enhanced CT image shows converging mesenteric vessels and fat (white arrows) intersecting the distal part of the stomach (black arrows) and the right gastric artery (arrowhead). Traction and distortion of the distal part of the stomach are also seen. **(b)** Transparent volume-rendered CT image shows a cluster of intestine (arrowheads) in the lesser sac, with a beak shape (arrows) pointing toward the lesser curvature of the stomach (*S*). Surgery confirmed herniated intestine in the lesser sac protruding through a defect in the lesser omentum. (Case courtesy of Yasuhito Iseki, MD, Osaka City University Graduate School of Medicine, Osaka, Japan.)

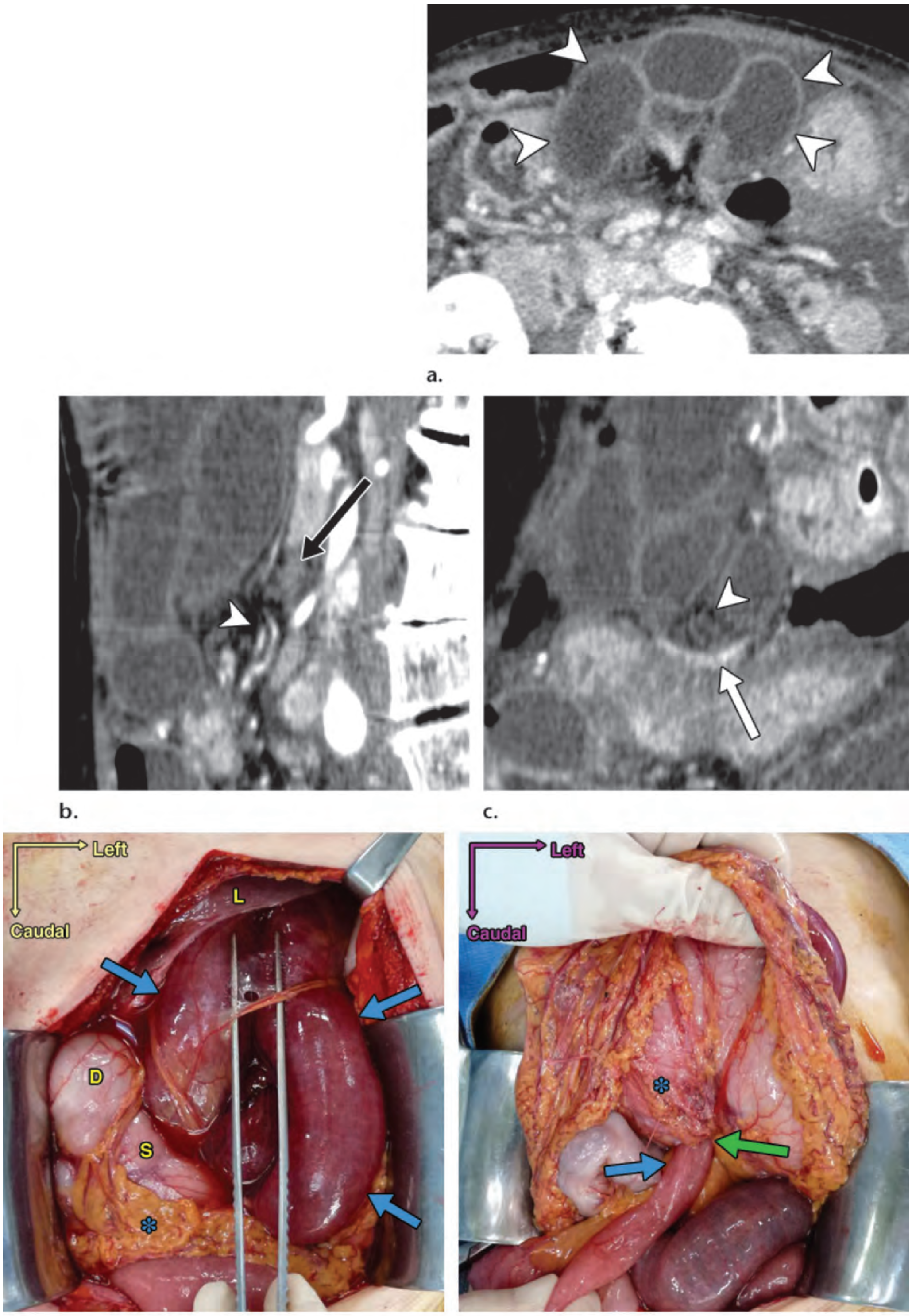
large intestine is involved, the presence of mesenteric vessels between the inferior vena cava and portal vein is also diagnostic (25) (Fig 11). An anteriorly compressed portal vein by the herniated viscera may also be seen on volume-rendered images of the portal venous system (45).

Other Types of Lesser Sac Hernia

Internal hernias through the lesser omentum, greater omentum, or transverse mesocolon may also appear as lesser sac hernias. These are characterized as herniation through an abnormal opening in a mesentery or peritoneal ligament.

Hernias into the lesser sac through the lesser omentum are extremely rare (46). The lesser omentum is composed of two contiguous components, the gastrohepatic and hepatoduodenal ligaments (30). The gastrohepatic ligament covers the lesser sac anteriorly, connecting the lesser curvature of the stomach and the proximal duodenum with the liver (36). Anatomic landmarks are the left and right gastric arteries and veins running along the lesser curvature. The hepatoduodenal ligament forms the right edge of the lesser omentum. In this type, the hernia orifice is located above the left or right gastric vessels (Fig 12).

Hernias through only one leaf of the greater omentum are classified as lesser sac hernias (Fig 13) because the intervening space between the anterior and posterior leaves of the greater



a. b. c. d. e.

Figure 13. Combined lesser sac hernia through the greater and lesser omenta in a 75-year-old woman who presented with epigastric pain. **(a)** Axial contrast-enhanced CT image shows closed-loop intestine (arrowheads) in the anterior portion of the peritoneal cavity. **(b, c)** Oblique MPR CT images show the hernia orifice (arrowhead) below the transverse colon (black arrow in **b**) and above the right gastric vein (white arrow in **c**). **(d)** Intraoperative photograph (anterior view) shows incarcerated intestine (blue arrows) in front of the lesser omentum. * = anterior leaf of the greater omentum, *D* = duodenum, *L* = liver, *S* = stomach. **(e)** Intraoperative photograph (anterior view) with the greater omentum reflected shows the small intestine (blue arrow) entering a defect (green arrow) in the posterior leaf of the greater omentum (*). Approximately 60 cm of herniated intestine was seen to be dilated and congestive but not infarcted, and resection of the herniated intestine was not performed. The greater omentum was sectioned, and the defect in the lesser omentum was closed. (Case courtesy of Atsuo Imagawa, MD, Bell Land General Hospital, Sakai, Japan.)

omentum is continuous with the lesser sac if fusion is incomplete (47).

A lesser sac hernia through the transverse mesocolon is usually classified as a transverse mesocolon–related hernia. This type is explained in the section on "Transverse Mesocolon–related Hernias."

With lesser sac hernias other than foramen of Winslow hernias, a normal appearance of the foramen of Winslow at multidetector CT represents a key finding (48).

Combined Lesser Sac Hernia

Openings associated with the lesser sac are not one-way. Herniated intestine may exit from the lesser sac into the greater peritoneal cavity through an opening other than the entry point in rare cases (Fig 13). Several combinations of entry and exit sites have been reported (42,47,49,50).

Transverse Mesocolon–related Hernia

Transverse mesocolon–related hernias are herniations through or into an abnormal defect in the transverse mesocolon. Anatomically, the transverse mesocolon suspends the transverse colon from the posterior parietal peritoneum and contains the middle colic artery and vein (30,35). Recently, an increasing number of cases of transverse mesocolon–related hernia after Roux-en-Y anastomosis surgery have been reported (9,15) and are described in another section ("Roux-en-Y Anastomosis–related Hernia"). However, transverse mesocolon–related hernias without a history of gastric bypass surgery remain uncommon.

Transverse mesocolon–related hernias can be subclassified into two subtypes according to the degree of the defect: *(a)* transmesenteric, indicated by the presence of a complete defect in the transverse mesocolon; or *(b)* intramesenteric, indicated by the presence of a defect in only the posterior peritoneal layer of the transverse mesocolon (51). Most cases are the transmesenteric subtype. In this subtype, the herniated intestine enters the lesser sac, unless the defect is related to previous surgery (42,48,51). With the intramesenteric type, the herniated viscera are trapped within the transverse mesocolon itself, and a saclike appearance can be observed.

With a transverse mesocolon–related hernia, the herniated viscera displace the transverse colon anteriorly and inferiorly (48).

Pericecal Hernia

Pericecal hernias are herniations into an unusual recess near the cecum. Four kinds of pericecal recesses have been defined: superior ileocecal recess, inferior ileocecal recess, retrocecal recess, and paracolic sulci. Furthermore, additional recesses may arise from individual variations in the rotation and peritoneal fusion process. All of these recesses represent potential hernia orifices (52). In addition to these congenital recesses, acquired conditions such as adhesion may cause a pericecal hernia (53). However, the diagnostic features and surgical treatment do not differ (4).

CT findings of pericecal hernia are characteristic. A saclike appearance is seen, and the hernia sac displaces the cecum and ascending colon anteriorly or medially (54) (Fig 14).

Sigmoid Mesocolon–related Hernia

The sigmoid mesocolon suspends the sigmoid colon from the posterior parietal peritoneum. The pathogenesis and subclassification of sigmoid mesocolon–related hernias is somewhat confusing. Sigmoid mesocolon–related hernias can be classified into three subtypes, as reported by Benson and Killen (55): transmesosigmoid, intramesosigmoid, and intersigmoid.

Transmesosigmoid and intramesosigmoid hernias are herniations through or into an abnormal defect in the sigmoid mesocolon itself. A transmesosigmoid hernia is defined as a herniation through a complete defect in both of the peritoneal layers of the sigmoid mesocolon, whereby no hernia sac is present. An intramesosigmoid hernia is a herniation into an abnormal defect in only one peritoneal layer, whereby the herniated viscera are trapped in the sigmoid mesocolon within a sac.

On the other hand, an intersigmoid hernia involves the intersigmoid fossa, a congenital retroperitoneal fossa that is located just above and behind the apex of the root of the sigmoid mesocolon. This fossa is formed during the fusion of the lower part of the left mesocolon and the posterior parietal peritoneum (56). Up to 70% of all bodies are said to have this fossa, and when it is large enough, small bowel loops can herniate into it (55).

At CT, the hernia orifice can be observed between the sigmoid colon and the left psoas major muscle in all three subtypes (57,58). Among them, the key to diagnosis of a transmesosigmoid hernia is absence of a saclike appearance. In contrast, intramesosigmoid and intersigmoid hernias show a saclike appearance, and CT findings of these two subtypes show substantial similarity, although the hernia orifices theoretically lie in different locations (Figs 15, 16). The sigmoid mesocolon contains the sigmoid arteries and veins and the superior rectal artery and vein (30). At multidetector CT, splaying of the sigmoid vessels,

Figure 14. Pericecal hernia in an 83-year-old woman with a 1-day history of nausea and right lower abdominal pain. **(a)** Axial contrast-enhanced CT image shows incarcerated intestine with a saclike appearance (arrowheads) that displaces the ascending colon (arrow) medially. **(b)** Oblique MPR CT image clearly shows the hernia orifice (arrows). Laparoscopic surgery showed incarcerated intestine in a hernia sac lateral to the ascending colon. (Case courtesy of Keigo Yasumasa, MD, JCHO Osaka Hospital, Osaka, Japan.)

a. b.

as if they are wrapping the hernia sac, may suggest an intramesosigmoid hernia (58).

Falciform Ligament Hernia

A falciform ligament hernia is a herniation through an abnormal opening in the falciform ligament of the liver. Anatomically, the falciform ligament attaches the anterior surface of the liver to the anterior abdominal wall. The small bowel is the most common viscus passing through a defect in the falciform ligament, but the omentum and colon have also been reported as hernia contents (60).

Although the falciform ligament consists of two peritoneal layers, no reported cases have shown a saclike appearance. This suggests that the abnormal openings have arisen in both peritoneal layers. A falciform ligament hernia should be considered when a closed-loop intestine is seen in front of or slightly caudal to the liver (Fig 17).

The round ligament is the inferior border of the falciform ligament (61). The hepatic falciform artery and paraumbilical veins run alongside the round ligament but are usually difficult to detect, even at multidetector CT. The round ligament itself represents the obliterated umbilical vein and is visible at multidetector CT, appearing as a thin hyperattenuating cord extending from the left hepatic hilum to the umbilicus (61). This structure may serve as a landmark for the falciform ligament.

Pelvic Internal Hernia

Pelvic internal hernias are a heterogeneous group of internal hernias that occur in the pelvis. The most frequently encountered type is a broad ligament hernia.

Broad Ligament Hernia

A broad ligament hernia is a herniation through or into an abnormal opening in the left or right broad ligament of the uterus. Although defects in the broad ligament may be congenital or acquired, 80% of broad ligament defects have been identified in multiparous women (62). The most common hernia content is the small intestine. Herniations of the colon, ovary, and ureter have also been reported (63).

Anatomically, the broad ligaments extend from the uterus to the lateral pelvic wall as drapes. The space between the two peritoneal layers of the broad ligament is known as the parametrium.

According to the report by Hunt (64), broad ligament hernias can be classified into two subtypes, fenestra or pouch type, according to the degree of the defect. The fenestra type is a herniation through both peritoneal layers of the broad ligament. No hernia sac is present, and the herniated intestine is located lateral to the uterus in the pelvic cavity (65). The pouch type is a herniation into a defect in only one of the two peritoneal layers of the broad ligament. This subtype is much less frequent and manifests as herniated viscera within a sac trapped in the parametrium.

The superior free edge of the broad ligament is formed medially by the fallopian tube and laterally by the suspensory ligament of the ovary (66). Landmark vessels of the broad ligament are the tubal and ovarian branches of the ovarian and uterine vessels, which run inside the superior portion of the ligament. The uterine artery and venous plexus, which run along the inferior border of the broad ligament, are also key vessels.

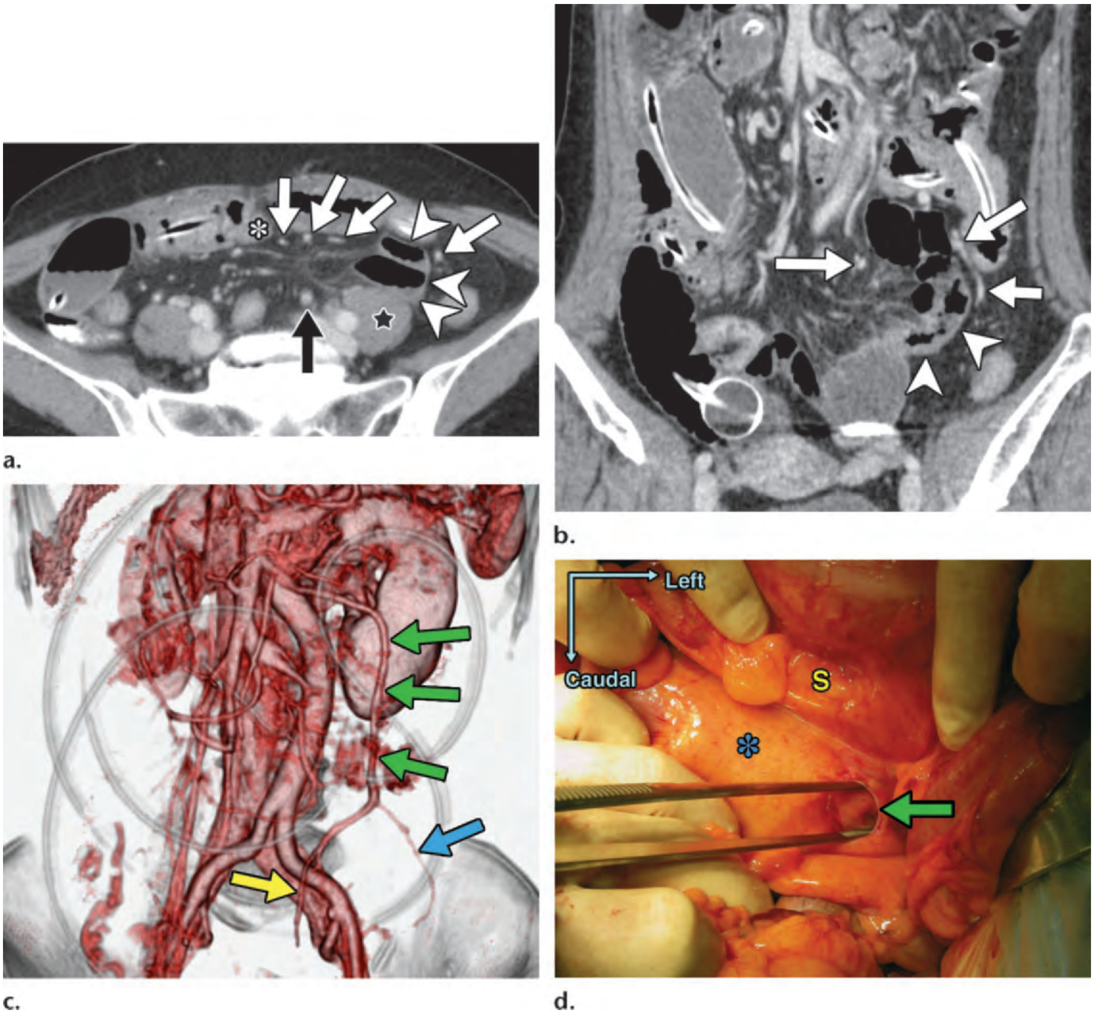


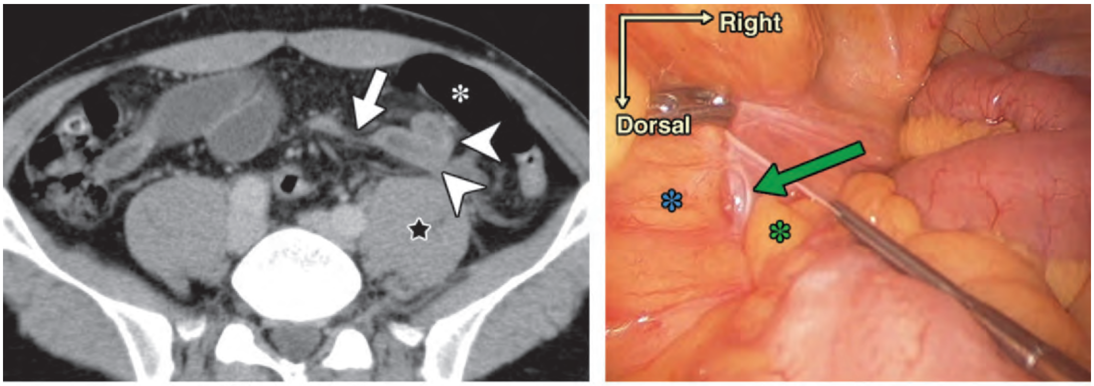
Figure 15. Intramesosigmoid hernia in a 56-year-old woman with acute abdominal pain and vomiting. **(a)** Axial contrast-enhanced CT image shows incarcerated intestine within a sac (arrowheads) and enlarged, stretched mesenteric vessels in the hernia orifice between the sigmoid colon (*) and left psoas major muscle (★). The hernia orifice also separates the sigmoid vessels (white arrows) and superior rectal vessels (black arrow). **(b)** Coronal MPR CT image shows sigmoid and superior rectal vessels (arrows) wrapping the hernia sac (arrowheads) visually. **(c)** Portal venous phase 3D CT angiogram clearly depicts the separation of one of the sigmoid veins (blue arrow) and the superior rectal vein (yellow arrow). Green arrows = inferior mesenteric vein. **(d)** Intraoperative photograph (anterior view) after reduction shows a 2-cm-diameter defect (arrow) in only one peritoneal layer of the sigmoid mesocolon (*). The defect was surgically closed. *S* = sigmoid colon. (Fig 15a, 15b, and 15d adapted and reprinted, with permission, from reference 58. Fig 15c courtesy of Hironori Shigeoka, MD, Osaka Prefectural Medical Center for Respiratory and Allergic Diseases, Habikino, Japan.)

At multidetector CT, coronal MPR images help define a defect in the broad ligament by directly depicting mesenteric vessels of herniated intestine penetrating the broad ligament (63,65,67) (Fig 18). Enlargement of the distance between the uterus and ovary, deviating in opposite directions, has been reported as another diagnostic finding for broad ligament hernia (65).

Internal Supravesical Hernia

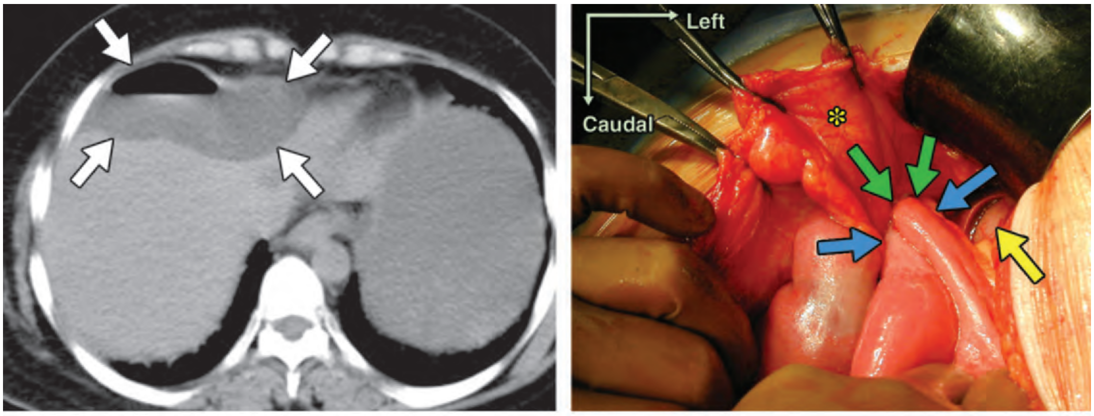
The supravesical fossa is a triangular area bounded medially by the median umbilical ligament (the urachus), laterally by the left or right medial umbilical ligament (the remnant of the umbilical artery), and inferiorly by the peritoneal reflection passing from the anterior abdominal wall to the dome of the urinary bladder (69). When intestine that has herniated into this supravesical fossa protrudes into the anterior abdominal wall, an external supravesical hernia develops; this type is not included in internal hernias. Less commonly, intestine herniated through the supravesical fossa passes downward into a space around the urinary bladder and forms an internal supravesical hernia, which is included in internal hernias.

With an internal supravesical hernia, herniated intestine usually passes into the retropubic space of Retzius, showing a characteristic CT finding of herniated intestine in front of the compressed



a. b.

Figure 16. Intersigmoid hernia in a 37-year-old man with sudden-onset left lower abdominal pain. **(a)** Axial contrast-enhanced CT image shows closed-loop intestine (arrowheads) and a hernia orifice (arrow) between the sigmoid colon (*) and left psoas major muscle (★). **(b)** Intraoperative photograph (superior view) during laparoscopic surgery after reduction shows a 1-cm-diameter defect (green arrow) where the root of the sigmoid mesocolon (blue *) attaches to the parietal peritoneum (green *). The hernia orifice was surgically closed. (Fig 16a courtesy of Sho Toyoda, MD, Bell Land General Hospital, Sakai, Japan. Fig 16b adapted and reprinted, with permission, from reference 59.)



a. b.

Figure 17. Falciform ligament hernia in a 40-year-old woman with a 6-day history of abdominal pain and vomiting. **(a)** Axial nonenhanced CT image shows incarcerated intestine (arrows) in front of the anterior and medial segments of the liver. **(b)** Intraoperative photograph (anterior view) shows incarceration of the intestine (blue arrows) through a small defect (green arrows) in the falciform ligament (*) of the liver. The herniated intestine was viable and was not resected. The falciform ligament was sectioned. Yellow arrow = lateral segment of the liver.

urinary bladder on the left or right (70) (Fig 19). A saclike appearance is also observed.

Other Types of Pelvic Internal Hernias

Other types of pelvic internal hernias are extremely rare. Only four cases of hernia through a defect of the pouch of Douglas have been reported in the English literature (71,72). As for internal hernias through a defect of the perirectal fossa, only two English reports have been found (5,73). A reported CT finding in each type is a cluster of intestinal loops in the pouch of Douglas or in the lateral side of the rectum.

Roux-en-Y Anastomosis–related Hernia

Reconstruction of a Roux-en-Y anastomosis is one of the common and increasing procedures in bariatric, gastric, and biliary surgeries (6,8). Internal hernia is a major complication of this anastomosis and results more commonly after laparoscopic gastric bypass surgery than open surgery (11). The reported incidence of internal hernia after laparoscopic Roux-en-Y gastric bypass surgery is between 0.2% and 9% (7).

Three subtypes of transmesenteric-type hernias occur with relation to this procedure: transmesocolic, jejunojejunostomy mesenteric, and Petersen hernias (7,8) (Fig 20). Transmesocolic hernia occurs through the surgical defect in the transverse mesocolon where the Roux limb passes. This is a complication peculiar to retrocolic reconstruction. Jejunojejunostomy mesenteric hernia is a herniation through the defect of the small bowel mesentery of the jejunojejunostomy site. Petersen hernia

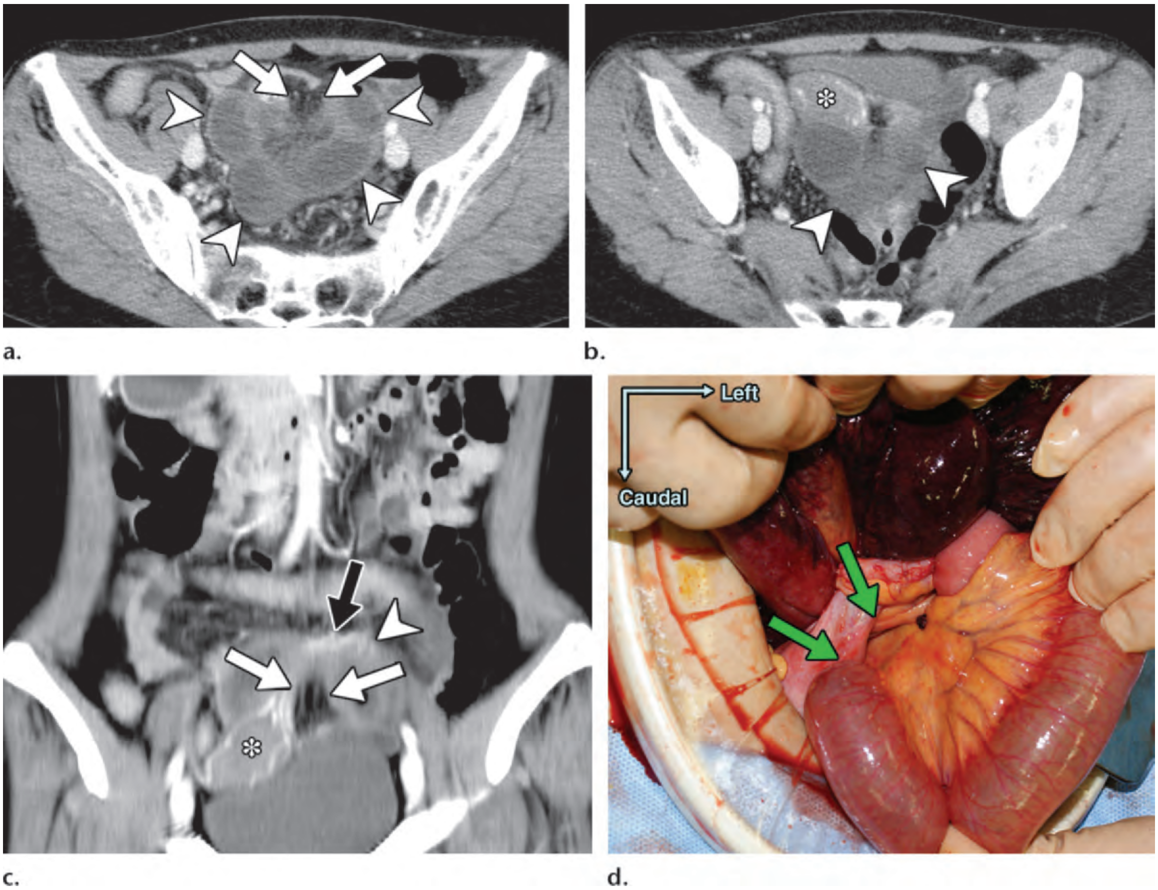


Figure 18. Broad ligament hernia in a 58-year-old woman with a 1-day history of intermittent abdominal pain and vomiting and a history of three normal pregnancies. **(a, b)** Axial contrast-enhanced CT images obtained at different levels show a cluster of small bowel loops in the pouch of Douglas (arrowheads) and crowding mesenteric vessels (arrows). The uterus (*) is deviated inferiorly and to the right. **(c)** Coronal MPR CT image shows the hernia orifice (white arrows) below the tubal and ovarian branches (black arrow) of the left ovarian and uterine vessels. Enlargement of the distance between the uterus (*) and the left ovary (arrowhead) is also seen. The patient's abdominal pain acutely intensified, and open surgery was performed. **(d)** Intraoperative photograph (anterior view) shows incarceration of the small intestine through a thumb-tip–sized defect (arrows) in the left broad ligament of the uterus. Approximately 70 cm of incarcerated intestine was infarcted and was resected, and the broad ligament was sectioned. (Fig 18a and 18d adapted and reprinted, with permission, from reference 68. Fig 18b and 18c courtesy of Yukio Nishiguchi, MD, Osaka City General Hospital, Osaka, Japan, and Tetsuro Ikeya, MD, Osaka City University Graduate School of Medicine, Osaka, Japan.)

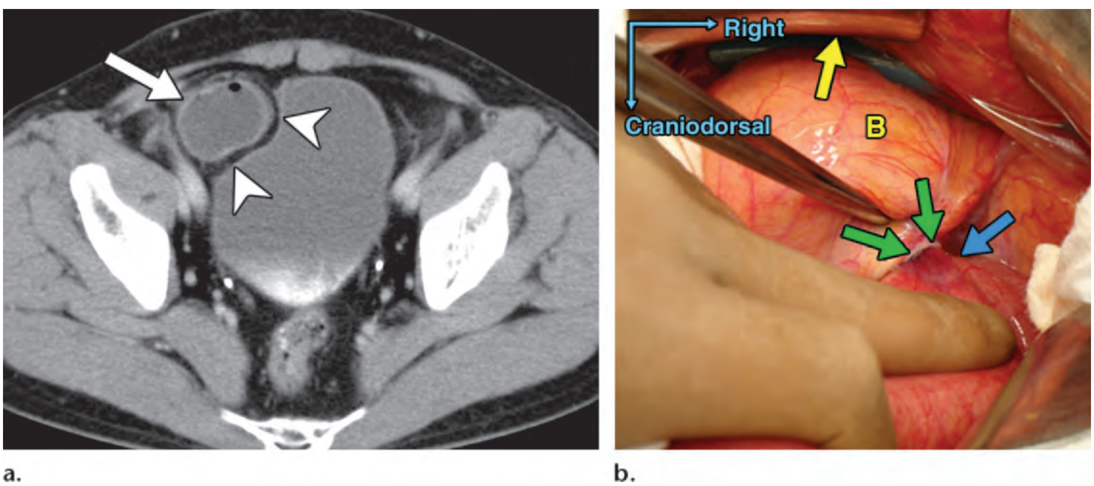


Figure 19. Internal supravesical hernia in a 74-year-old man with a 1-day history of right lower abdominal pain. **(a)** Axial contrast-enhanced CT image shows incarcerated intestine with a saclike appearance (arrow) that compresses the anterior wall (arrowheads) of the urinary bladder on the right. **(b)** Intraoperative photograph (superoanterior view) shows incarceration of the ileum (blue arrow) into the right supravesical fossa (green arrows). Approximately 7 cm of intestine was infarcted and was resected. The defect was approximately 2 cm in diameter. The hernia sac was resected, and the hernia orifice was closed with sutures. *B* = urinary bladder, yellow arrow = pubis.

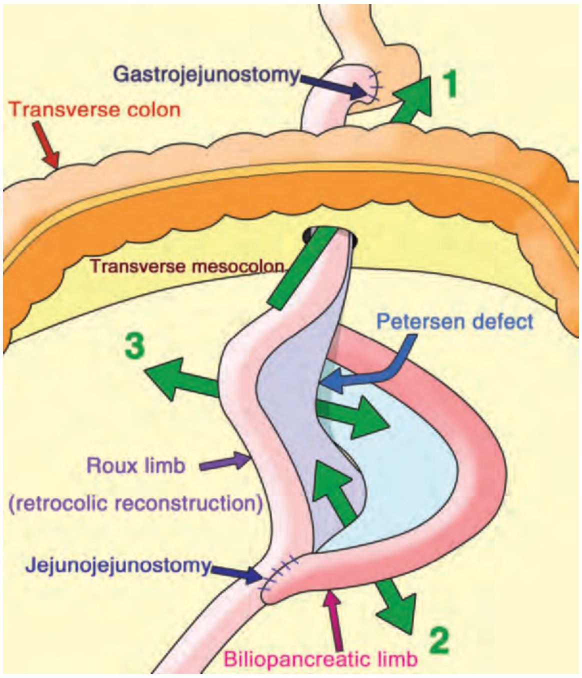
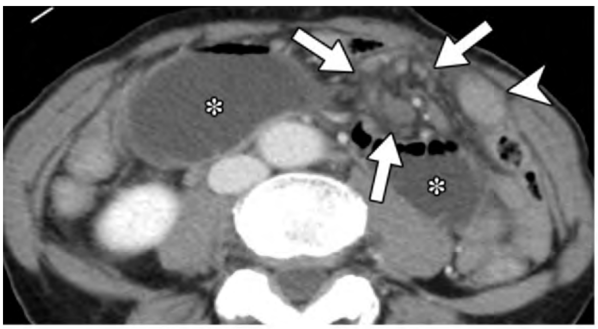


Figure 20. Drawing shows the anatomic sites of transmesenteric-type internal hernias after Roux-en-Y anastomosis reconstruction: *1* = transmesocolic hernia, *2* = jejunojejunostomy mesenteric hernia, *3* = Petersen hernia.

Figure 21. Petersen hernia in a 60-year-old woman with acute abdominal pain and vomiting. The patient had a history of laparoscopic distal gastrectomy and antecolic reconstruction of a Roux-en-Y anastomosis for gastric cancer performed 11 months earlier. **(a)** Axial contrast-enhanced CT image shows a dilated biliopancreatic limb (*) and mesenteric swirl (arrows) behind the Roux limb (arrowhead). **(b)** Coronal MPR CT image shows a cluster of intestine (★) with engorged mesenteric lymph nodes located in the left lower quadrant, as well as a dilated biliopancreatic limb (*). Surgery confirmed herniation of a long segment of small intestine, including jejunojejunostomy through a Petersen defect. Arrowhead = Roux limb, black arrow = jejunojejunostomy, white arrow = gastrojejunostomy.



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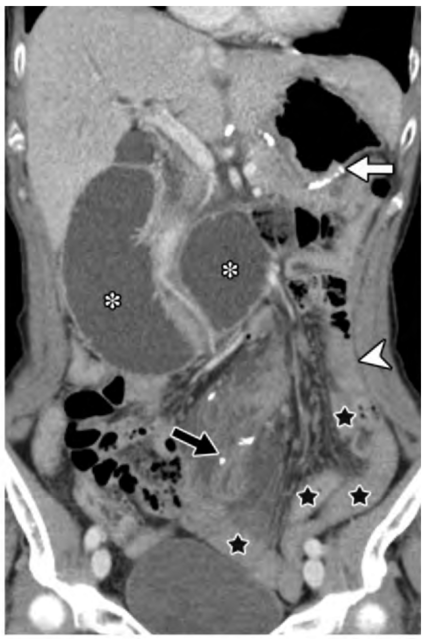

b.

is a herniation through the potential space called the Petersen defect, which is located between the jejunal mesentery of the Roux limb and transverse mesocolon. A deformed and displaced Roux limb, biliopancreatic limb, and transverse colon may serve as landmarks of these hernias (8).

At CT, the anatomy in patients who have undergone Roux-en-Y gastric bypass surgery is complex (11). In addition, Roux-en-Y anastomosis–related hernias without intestinal obstruction are sometimes observed. Therefore, many useful CT signs that are based on identification of the effects of herniation have been studied. These CT signs include mesenteric swirl, clustered small bowel loops, the “mushroom” sign (a mushroom-shaped mesenteric root between the superior mesenteric artery and the distal mesenteric arterial branch), the “hurricane eye” sign (distal tubular mesentery with surrounding small bowel loops), a small bowel loop behind the superior mesenteric artery, abnormal position of the jejunojejunostomy, and "weeping mesentery" (edematous mesentery with enlarged lymph nodes) (7,11–13) (Fig 21).

Conclusion

The advent of multidetector CT has enabled preoperative diagnosis of internal hernias, with a correlated expansion of the roles expected of radiologists. Radiologists should familiarize themselves with diagnostic multidetector CT findings for the various types of internal hernias.

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