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INVITED REVIEW

Four "fine" messages from four kinds of "fine" forgotten ligaments of the anterior abdominal wall: have you heard their voices?

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Abstract

On the posterior aspect of the anterior abdominal wall, there are four kinds of "fine" ligaments. They are: the round ligament of the liver, median umbilical ligament (UL), a pair of medial ULs, and a pair of lateral ULs. Four of them (the round ligament, median UL, and paired medial ULs) meet at the umbilicus because they originate from the contents of the umbilical cord. The round ligament of the liver originates from the umbilical vein, the medial ULs from the umbilical arteries, and the median UL from the urachus. These structures help radiologists identify right-sided round ligament (RSRL) (a rare, but surgically important normal variant), as well as to differentiate groin hernias. The ligaments can be involved in inflammation; moreover, tumors can arise from them. Unique symptoms such as umbilical discharge and/or location of pathologies relating to their embryology are important in diagnosing their pathologies. In this article, we comprehensively review the anatomy, embryology, and pathology of the "fine" abdominal ligaments and highlight representative cases with emphasis on clinical significance.

Keywords Hepatic round ligament · Right-sided round ligament · Umbilical ligament · Groin hernia

Introduction

On the posterior wall of the anterior abdominal wall, there are forgotten ligaments. They are "fine," cord-like structures, and little attention is paid to them in daily radiological image interpretation. However, they help radiologists to identify surgically important variations and rare emergency conditions, as well as to differentiate groin hernias.

We reviewed the anatomy and embryology of these ligaments and then highlighted their radiological significance, and the pathologies that can involve them.

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Anatomy

Four "fine" ligaments of the posterior aspect of the anterior abdominal wall meet at the umbilicus (Fig. 1). They are the round ligament of the liver (ligamentum teres hepatis), a pair of medial umbilical ligaments (ULs), and the median UL. In addition, there are two peritoneal ligaments; they are the paired lateral ULs containing the inferior epigastric arteries and veins that anastomose with the superior epigastric vessels and do not meet the other ligaments at the umbilicus [1].

The round ligament of the liver runs between the umbilicus and the umbilical portion of the portal vein, usually located on the left side of the middle hepatic vein. The round ligament of the liver is covered by the falciform ligament of the liver (peritoneal flap) and forms the inferior edge of the falciform ligament (Fig. 2) [2].

The median UL runs vertically on the lower abdominal wall between the umbilicus and bladder. The medial ULs arise from the internal iliac arteries, run horizontally to the anterior abdominal wall along the lateral pelvic wall, and then turn craniomedially to the umbilicus.

The median and medial ULs are covered by the parietal peritoneum to form the median and medial umbilical folds, respectively, on the posterior aspect of the anterior

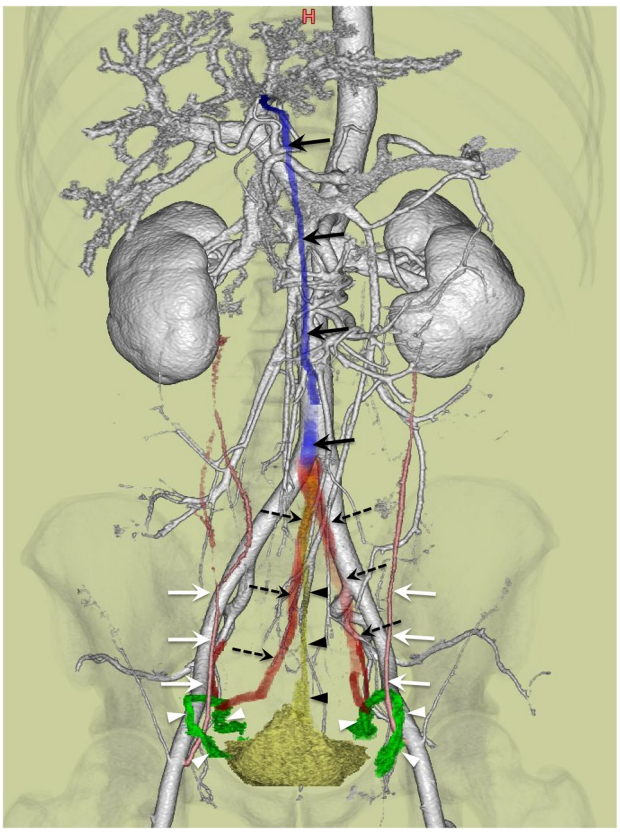

Fig. 1 Ligaments of the abdominal wall. Two single and two pairs of ligaments run along the posterior aspect of the anterior abdominal wall. They are the round ligament of the liver (blue, black arrows), median UL (yellow, black arrow heads), medial ULs (red, black dashed arrows), and lateral ULs (pink, white arrows). The green lines (white arrow heads) indicate the vas deferens (male) or the round ligaments of the uterus (female). They arise from the prostate or uterus, cross over the medial and lateral ULs, and enter the inguinal canals. UL, umbilical ligament

abdominal wall. The horizontal segment of the medial UL is also covered by the peritoneum to form a small ridge on the pelvic floor similar to the broad ligaments of the uterus (Fig. 3).

Embryology

Round ligament of the liver

In the fetus, the round ligament of the liver functions as the umbilical vein. Fetal blood, rich in oxygen and nutrients, flows from the placenta to the fetal heart via the umbilical vein, ductus venosum (Arantius' duct), and inferior vena cava.

After birth, the umbilical vein and ductus venosum are obliterated within 1 week and then become fibrous cords: the round ligament of the liver and the ligamentum venosum, respectively.

The relationship between the umbilical junction of the portal vein and the hilar plate of the liver arises through hepatic organogenesis. The primitive liver of about week 5 is symmetrical and connects with a pair of omphalomesenteric veins (the future superior mesenteric vein) and a pair of umbilical veins. The left omphalomesenteric and right umbilical veins atrophy at about month 2. (Fig. 4). In right-sided round ligament (RSRL), the left umbilical vein atrophies.

Median UL

In the fetus, the median UL is the urachus. The urachus connects the fetal bladder and umbilicus, and the allantoic duct connects the fetal umbilicus and placenta. After birth they are completely obliterated.

Medial ULs

The umbilical arteries arise from the internal iliac arteries and carry fetal blood to the placenta. After birth, they are completely obliterated and then recognized as the paired medial ULs [3].

Imaging Features Of Pathologic Conditions

Congenital Abnormalities

Round Ligament RSRL is a rare congenital abnormality with an incidence of approximately 0.4% [4, 5]. Previously, it was called left-sided gallbladder, because the gallbladder is sinister to the falciform ligament. However, from the viewpoint of embryological symmetry of the liver, the position of the round ligament is considered to be the basis of the condition.

To understand RSRL from the viewpoint of hepatic symmetry with the hilar plate (Rex–Cantlie's *line*), it is mandatory to be familiar with the liver "sectors" that are based on portal vein branching (Table 1, Fig. 5) [6]. In this concept, the liver is divided into four sectors: left lateral (Couinaud S2), left medial (S3, S4), right anterior (S5, S8), and right posterior (S6, S7) sectors.

Usually the round ligament attaches to the portal branch of segments 3 + 4 (left medial sector) to split S3 and S4. In cases of RSRL, on the other hand, the round ligament attaches to the portal branch of segments 5 + 8 (right anterior sector). The round ligament divides the right anterior sector into dorsal and ventral segments, which is different from Couinaud's S5 and S8.

Yamashita et al. [7] proposed a three-step method to identify RSRL:

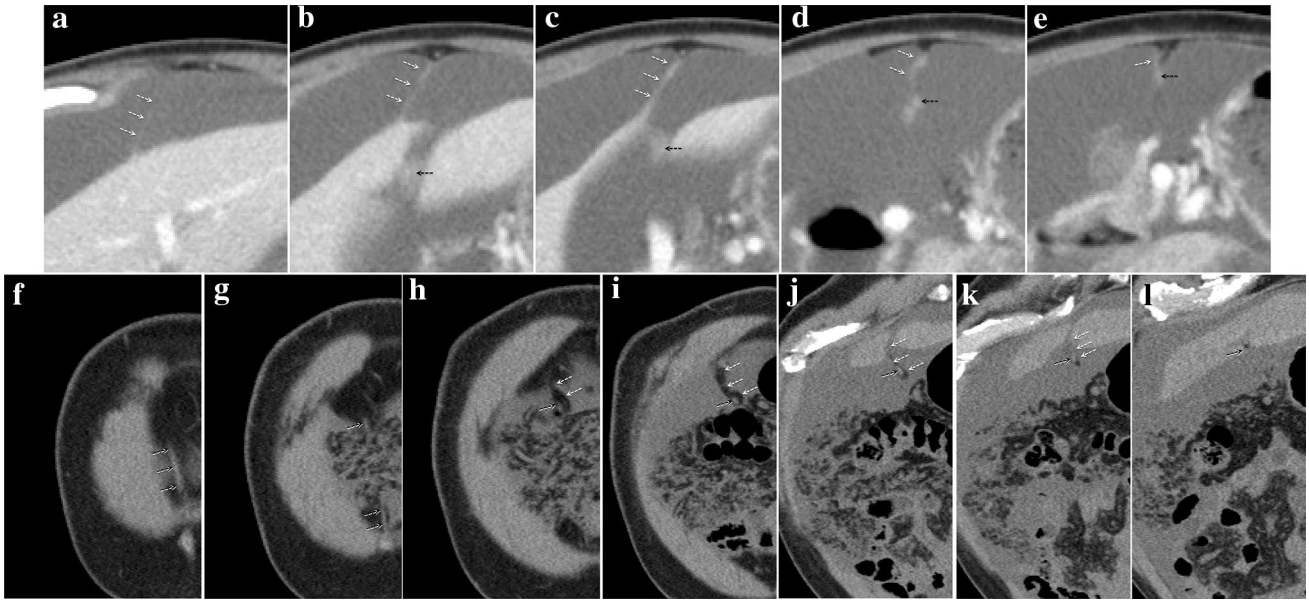

Fig. 2 Round ligament of the liver (**a**–**e** axial images; **f**–**l** coronal images). The round ligament of the liver (black dashed arrows) is commonly seen as a tubular structure and covered by a peritoneal flap (falciform ligament). It indicates the free edge of the falciform ligament. In this patient, the falciform ligament (white dashed arrows) is well demonstrated by massive ascites from carcinomatous peritonitis, causing thickening of the falciform ligament

1. Determine the axis connecting the umbilical point (UP) and main trunk of the portal vein (P_{MT}).
2. Identify the portal branch to the right posterior sector, right hepatic vein portal branch to the dorsal segment of the right anterior sector ($P_{r\text{-}AD}$), and portal branch to the left lateral sector ($P_{l\text{-}L}$), respectively.
3. Evaluate the branching portion of $P_{r\text{-}AD}$ and $P_{l\text{-}L}$ on the axis determined in step 1
   UP – $P_{r\text{-}AD}$ – $P_{l\text{-}L}$ – PMT: RSRL
   UP – $P_{l\text{-}L}$ – $P_{r\text{-}AD}$ – P_{MT}: normal

Laparoscopic cholecystectomy may be complicated because of an altered anatomical relationship between the round ligament and gallbladder. The falciform ligament conceals the confluence of the cystic duct to limit the operative field. There are several variations of portal vein branching and biliary tree confluence in patients with RSRL (Fig. 6) [4, 5]. Therefore, major hepatectomy may also be compromised because of the complex biliary confluence in RSRL [4].

Anomalous course of the round ligament (aberrant umbilical vein) is another congenital abnormality (Fig. 7). Developmental failure of the falciform ligament of the liver is thought to cause this condition [8]. The anomalous course and shortening of the round ligament of the liver may compress the stomach, causing postprandial epigastralgia or vomiting [9]. Surgical division of the round ligament of the liver relieves the symptoms [8].

Median UL The urachus persists to varying degrees at birth, i.e., patent urachus (no obliteration, 50%), urachal sinus (bladder-side obliteration, 15%), urachal diverticulum (umbilicus-end obliteration, 3–5%), and urachal cyst (incomplete obliteration with obliteration at both ends, 30%) [10].

Medial ULs Approximately 0.5%–0.8% of neonates are born with a single umbilical artery [11]. A right single umbilical artery is encountered more often (no statistical significance) [12]. These neonates are at higher risk of congenital anomalies (renal, cardiovascular, musculoskeletal) and are at a 15-fold risk for chromosomal abnormalities [11]. Even when isolated, this anomalous form has a higher risk for long-term respiratory morbidity [13].

Several cases of patent umbilical artery have been reported. Ureteral compression by the patent umbilical artery results in ureteral obstruction [14]. One case report of patent impar umbilical artery described an association with genitourinary anomalies and complex vascular anatomy [15].

Congenital/Noncongenital hernias

Falciform ligament hernias Internal herniation through congenital or acquired (by blunt trauma or iatrogenic causes) defects of the falciform ligament are rare. The incidence of falciform ligament hernia accounts for 0.2% of internal her-

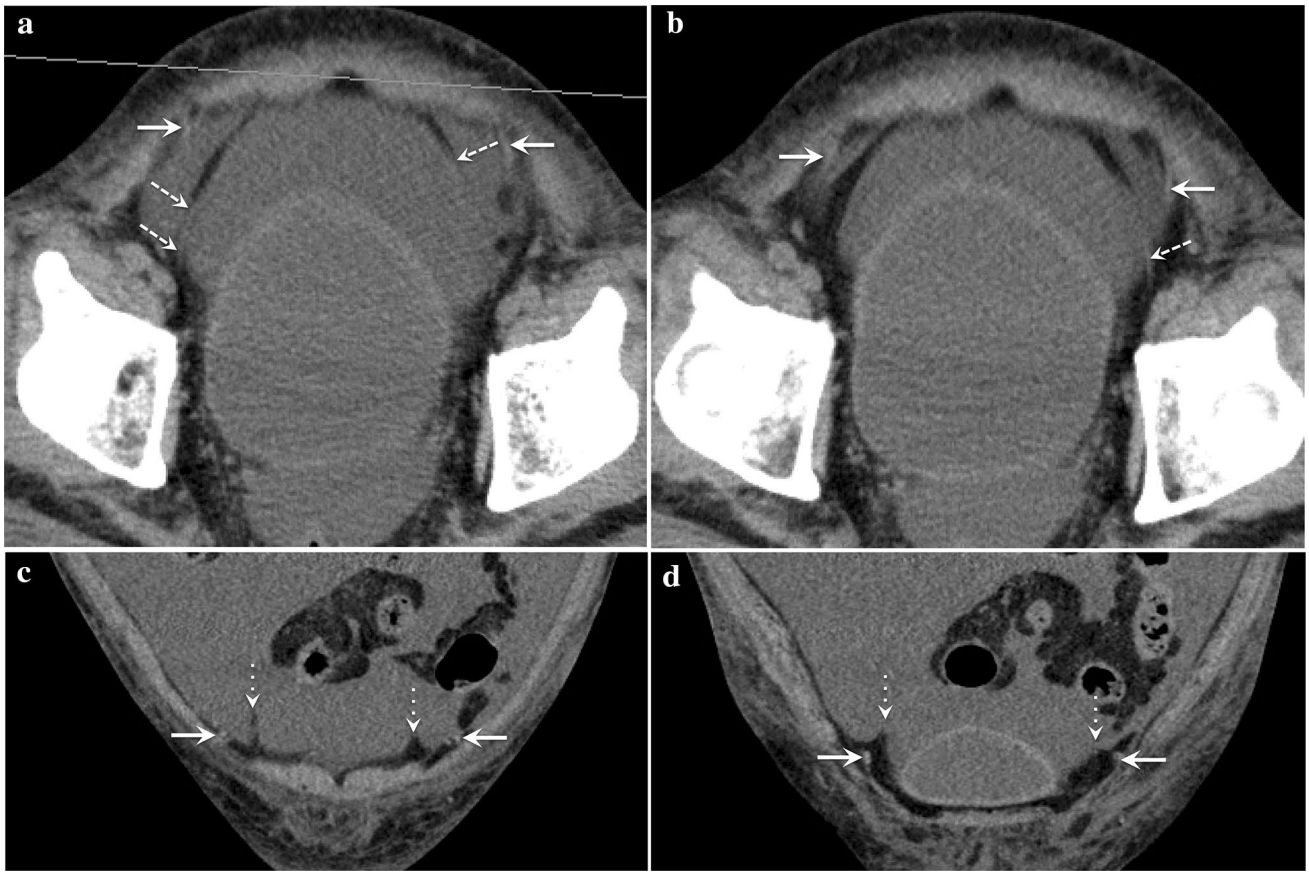

Fig. 3 Median and medial ULs (**a**, **b**, axial images; **c**, **d** coronal images). The lateral ULs (white arrows) and medial ULs (white dashed arrows) are indicated. The medial ULs form a small ridge of the pelvic floor, similar to the broad ligament of the uterus. In this patient, this small ridge is well visualized because of ascites. *UL* umbilical ligament

nias [16]. Herniated bowel or omentum may be observed ventral to the right lobe of the liver. The round ligament may be identified caudal to the herniated structure [17].

In abdominal radiographs or scout images in CT, Chilaiditi syndrome mimics falciform ligament hernia. However, strangulation is more often associated with falciform ligament hernia than Chilaiditi syndrome. The relationship between the bowel and round ligament is an important differentiating feature.

Lower abdominal fossae and groin hernias The ULs divide the abdominal wall into three areas (fossae) (Fig. 8) [1]. The lateral inguinal fossa (LIF) is cranial to the inguinal ligament and lateral to the lateral UL.

The medial inguinal fossa (MIF) is cranial to the inguinal ligament, between the lateral and medial ULs. In the MIF, direct herniation occurs from Hasselbach's triangle (defined by the edge of the rectus abdominis muscle), the inguinal ligament, and lateral ULs.

The supravesical fossa (SVF) is between the median and medial ULs. Supravesical herniation occurs in the SVF.

The femoral canal (FC) is a narrow area dorsocaudal to the inguinal ligament between the femoral vein and lacunar ligament (a tiny ligament on the pubic tuberosity). The femoral canal is located just caudal to the DIR and a femoral hernia occurring through the FC is sometimes confused with an indirect inguinal hernia [18].

(i) Direct inguinal hernia (Figs. 9,10)

Both direct inguinal hernia and femoral hernia occurs medial to the lateral UL [19]. Lateral displacement of the inguinal canal contents (spermatic cord/round ligament of the uterus, and fat) is a useful finding (lateral crescent sign) to differentiate direct inguinal hernia from femoral hernia, when the inguinal ligament is poorly visualized in cross-sectional images [20].

Inguinal vesical hernia is a rare condition, encountered in 1–4% of inguinal hernias [21]. Over the age of 50 years, the frequency is up to approximately 10% [21]. Herniation of the bladder into the scrotum, termed scrotal cystocele, is very rare. It occurs

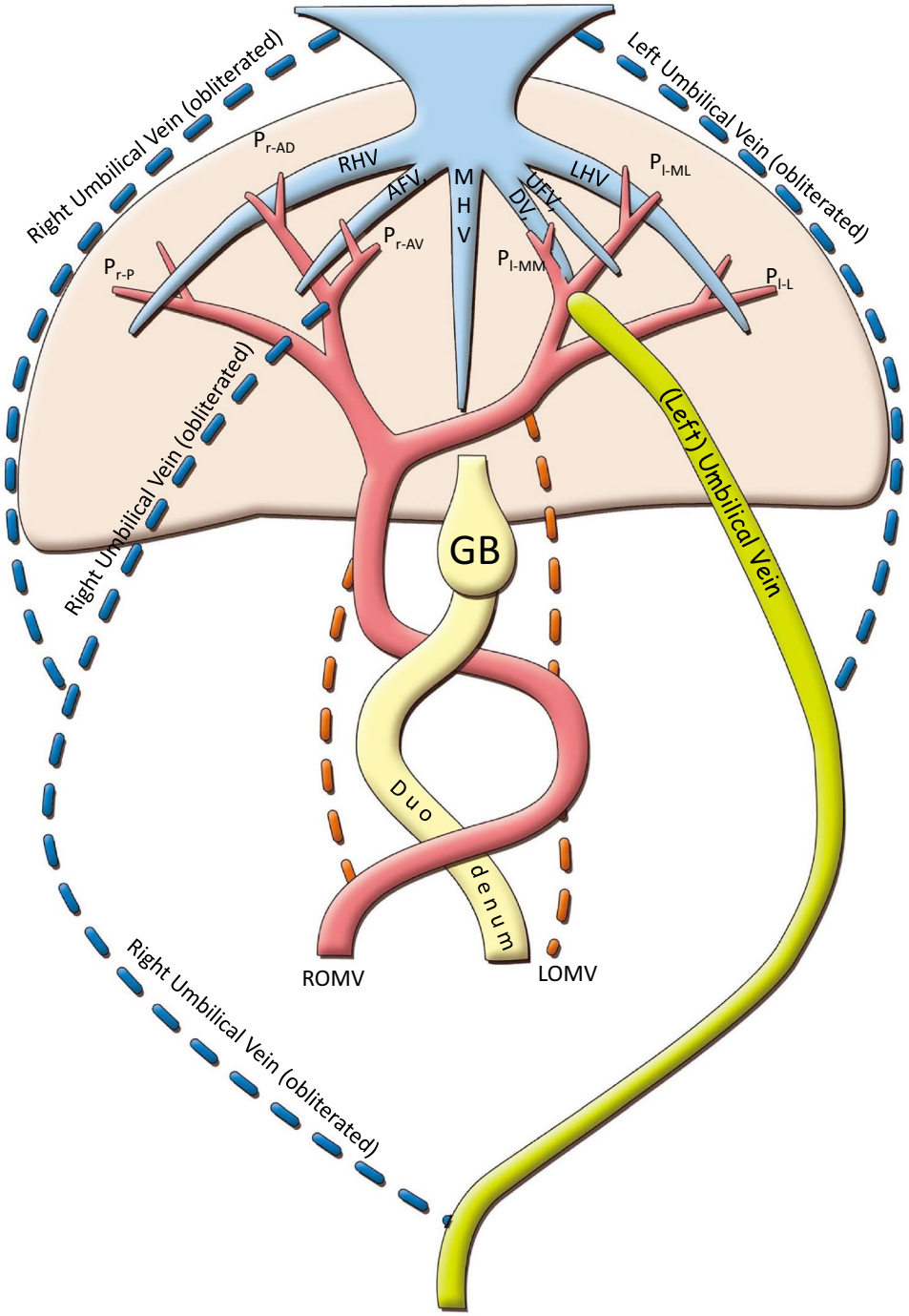

Fig. 4 Umbilical vein and omphalomesenteric vein. The superior portion of the left umbilical veins and the whole right umbilical vein are obliterated, and the residual left umbilical vein connects the placenta and primitive liver. The right and left omphalomesenteric veins have bridging veins. The right omphalomesenteric vein mainly forms the superior mesenteric vein, and the left vein atrophies. Thus, absolute symmetry is lost during organogenesis, but this is the reason the liver is considered to be symmetric to the hilar plane/Rex–Cantlie's line. Refer to Table 1 for anatomical terminology. *AFV* anterior fissure vein, *DV* ductus venosum, *LHV* left hepatic vein, *LOMV* left omphalomesenteric vein, *MHV* middle hepatic vein, *RHV* right hepatic vein, *ROMV* right omphalomesenteric vein, *UFV* umbilical fissure vein. $P_{l\text{-}L}$: portal vein (PV) to the left lateral sector (Couinaud S2). $P_{l\text{-}ML}$: PV to the left medial sector, lateral segment (S3). $P_{l\text{-}MM}$: PV to the left medial sector, medial segment (S4). $P_{r\text{-}AD}$: PV to the right anterior sector, dorsal segment (dorsal S5 + 8). $P_{r\text{-}AV}$: PV to the right anterior sector, ventral segment (ventral S5 + 8). $P_{r\text{-}P}$: PV to the right posterior sector (S6 + 7)

Table 1 Terminology of liver anatomy

Couinaud segments	Section based on bile ducts and hepatic artery	Sector based on portal vein
2	Left lateral section	Left lateral sector (Left posterior sector)
3		Left medial sector (Left paramedian sector)
4	Left medial section	
5, 8	Right anterior section	Right anterior sector (Right paramedian sector)
6,7	Right posterior section	Right posterior sector (Right lateral sector)

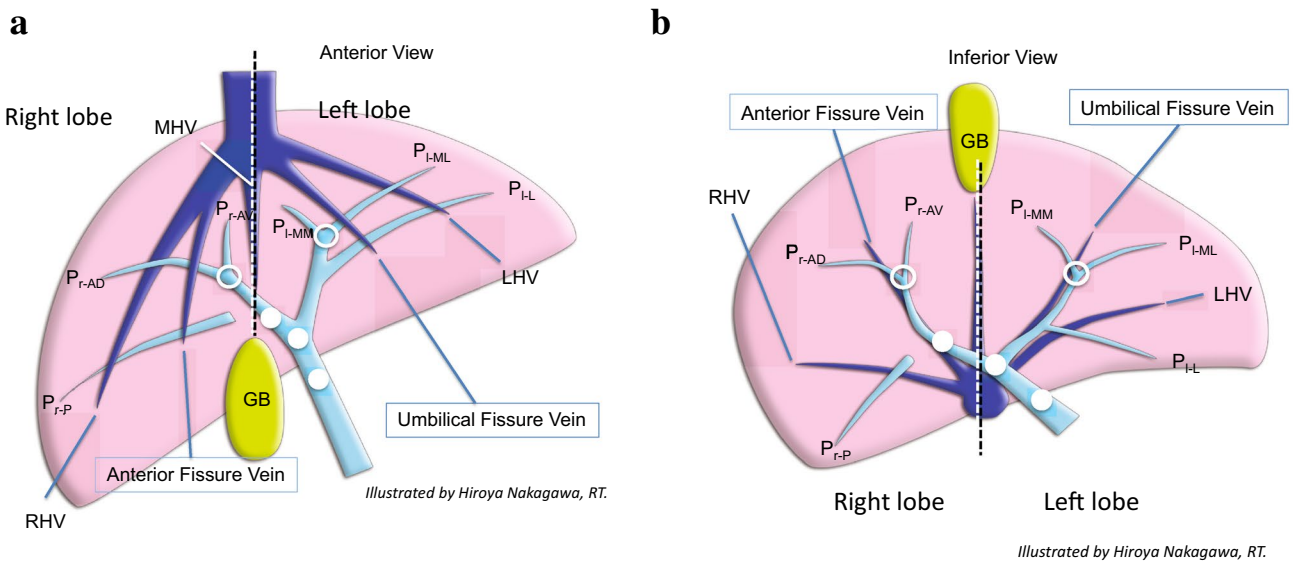

Fig. 5 Liver symmetry and umbilical point (**a** anterior view; **b** inferior view). The liver is considered to be symmetric to the hilar plane/Rex–Cantlie's line (dashed lines). Refer to Table 1 for anatomical terminology, and abbreviations are same as Fig. 4. White dots indicate branching point of $P_{r\text{-}P}$: peripheral dot, common bifurcation type; intermediate dot, trifurcation type; proximal dot, independent right posterior branch type. White circle in the left lobe (between $P_{l\text{-}ML}$ and $P_{l\text{-}MM}$) indicates the umbilical point of the round ligament in normal liver. White circle in the right lobe (between $P_{r\text{-}AD}$ and $P_{r\text{-}AV}$) indicates the umbilical point of the right-sided round ligament

unilaterally or bilaterally. Radiologically, the "pelvic Mickey Mouse" sign on transverse axial imaging or the "flying-saucer in the pelvis" sign on intravenous pyelogram are helpful signs to diagnose inguinal vesical hernia [22].

(ii) Indirect inguinal hernia

Indirect inguinal hernias occur in the LIF; hernia contents (usually gastrointestinal tract) enter the inguinal canal through the deep (lateral) inguinal ring (DIR in Fig. 8a) along the spermatic cord or along the round ligament of the uterus.

Ovarian hernia occurs in 15–20% of female inguinal hernias, often with the ipsilateral fallopian tube (Fig. 11) [23]. Ovarian torsion within an incarcerated inguinal hernia may occur [24]. A very exceptional case of a premature newborn with an inguinal hernia containing the entire uterus, fallopian tubes, and both ovaries has been reported [25].

Crossed testicular ectopia, also known as transverse testicular ectopia, is a rare congenital anomaly (Fig. 12). The anatomical relationship between the inguinal contents and lateral UL is same as indirect inguinal hernia. Both testes descend into the ipsilateral hemiscrotum [26]. Associations with persistent Müllerian duct syndrome, inguinal hernia, hypospadias, disorders of sex development, scrotal anomalies, testicular fusion, and common vas deferens have been reported [27-30].

(iii) Femoral hernia (Fig. 13)

Femoral hernias account for 5% of abdominal wall hernias and are much more common in older females [31]. The relationship to the lateral UL is useful to differentiate femoral hernia from indirect inguinal hernia. Compression of the femoral vein by the herniated structure in the femoral sac is easily evaluated on axial images [18]; it is also useful to differentiate femoral hernia from direct inguinal hernia. The simplest way to differentiate femoral hernia from inguinal hernia is to evaluate the relationship to the inguinal ligament when the inguinal ligament is recognized on coronal images [32]. Delabrousse et al. [33] reported that relationship to the pubic tubercle helps to differentiate groin hernias; femoral hernia is located more posteriorly to the tubercle.

(iv) Groin hernias with eponyms

Several hernias have eponyms. A Romberg hernia is any combination of two adjacent hernias of the inguinal or femoral region. It is also known as dual hernia, pantaloon hernia, or saddlebag hernia [34]. A more complex combination of groin hernias is reported in a case with an anomalous lateral UL [35].

Amyand's hernia (Fig. 14): Claudius Amyand (1660–1740, French surgeon) [36] reported the case of an 11-year-old boy with an inguinal hernia containing an inflamed appendix in 1736. Amyand's hernia accounts for 0.4–0.6% of inguinal hernia and 0.1% of appendicitis cases [37]. Losanoff and Basson [38] classified Amyand's hernia

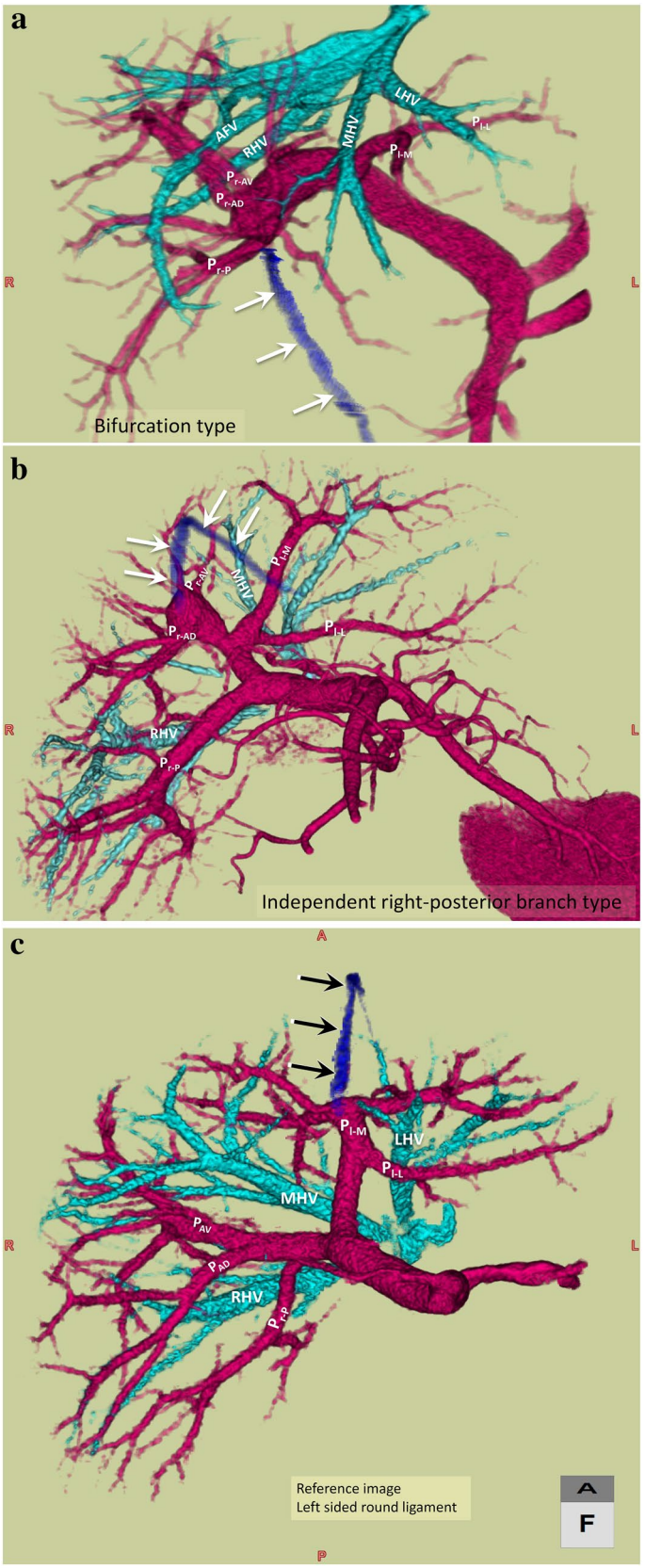

Fig. 6 Right-sided round ligament (RSRL) (**a** bifurcation type; **b** independent right posterior branch type; **c** most common anatomy for reference). Two cases of RSRL; the round ligament attaches to the portal branch of segments 5 + 8 (right anterior sector). In left-sided round ligament (the reference image), the round ligament attaches to the portal branch of segments 3 + 4 (left medial sector). Independent right posterior branch-type RSRL is difficult to recognize because $P_{r\text{-}P}$ and $P_{r\text{-}AD}$ are apt to be misidentified as the right main branch of the portal vein and P4, respectively. Positional relationship to the hepatic veins is important. Abbreviations are same as Fig. 4

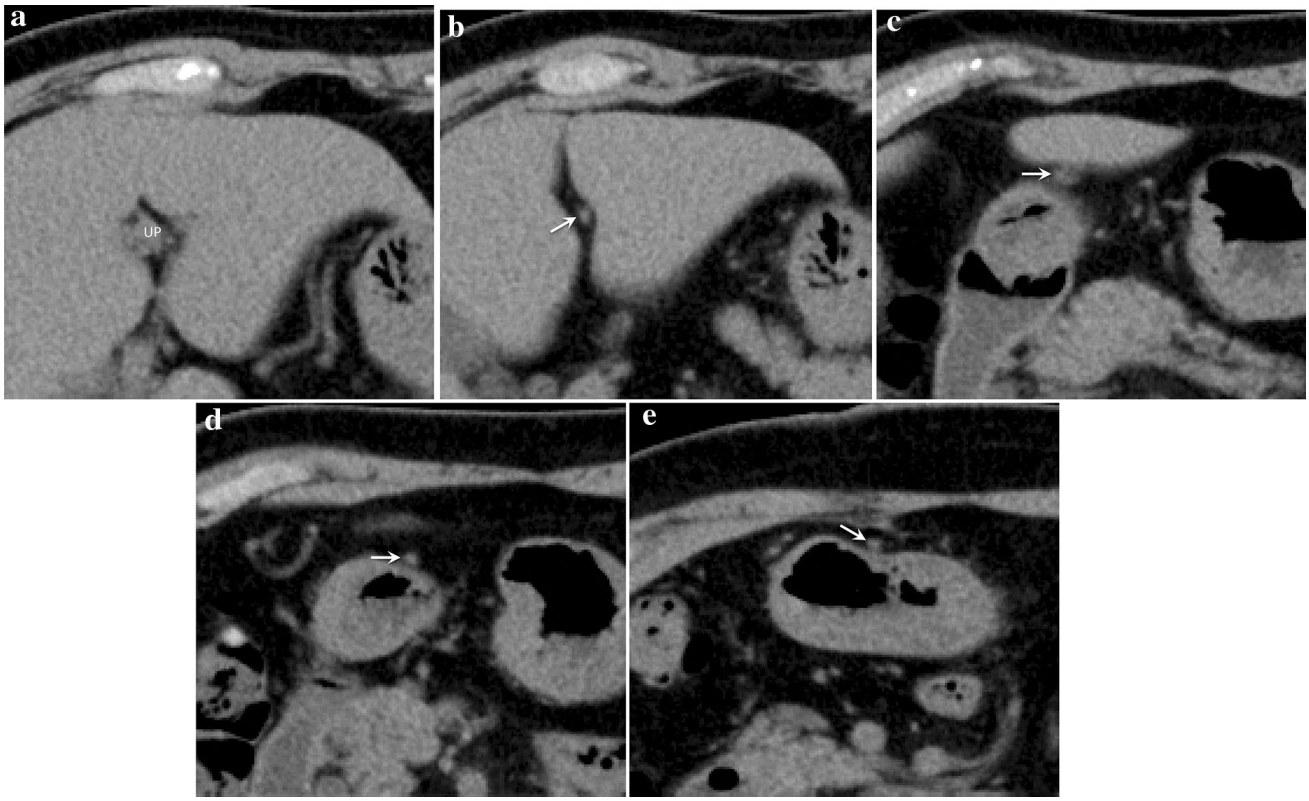

Fig. 7 Anomalous course of the round ligament (**a**–**e** axial images). Asymptomatic 82-year-old man with follow-up CT after colectomy for colon cancer. The round ligament (white arrows) runs between the stomach and the lateral segment of the liver. This finding may be associated with a defect of the falciform ligament of the liver. *UP* umbilical point

into four types: type 1, normal appendix; type 2, appendicitis localized in the sac; type 3, appendicitis with peritonitis; and type 4, appendicitis with other abdominal pathology. Left-sided Amyand's hernia can occur in patients with malrotation, situs inversus, or cecal vascule [39]. Direct Amyand's hernia and association with Maydl's hernia have also been reported [40].

Maydl's hernia (Fig. 15): Karel Maydl (1853–1903, Austrian surgeon) [41] first described two intestinal loops within a single hernia sac in 1895. A strangulated small intestinal loop exists in the peritoneal cavity (retrograde hernia by failure of reduction). Postural and manual reductions are contraindicated [42]. An intra-abdominal loop at the hiatus presents a "W" configuration. Association with Amyand hernia is reported [42]. Radiological findings consist of two pairs of intestinal loops in the inguinal canal and an intraperitoneal strangulated loop near the herniation orifice.

De Garengeot's hernia (Fig. 16): In 1731, Rene Jacques Croissant de Garengeot (1688–1759, Parisian surgeon) first described this hernia [43]. It is a rare (0.5–5%) type of femoral hernia containing the appendix, with female predominance (M:F = 1:5) [44]. Appendicitis can occur in 0.08–0.13% of de Garengeot's hernias [45]. Having performed the first appendectomy in a patient with de Garengeot's hernia in 1785, two possible etiologies are advocated: mass effect by the large cecum and/or malrotation of the intestine [46].

Most cases of Littre's hernia (herniation of Meckel's diverticulum) are inguinal (50%), umbilical (20%) or femoral (20%) [47].

Inflammatory processes

Round ligament Inflammation of the round ligament of the liver is a very rare condition (Fig. 17) [48]. Several case reports of abscess and necrosis of the ligament have been published [49]. Pseudocyst formation along the hepatoduodenal ligament (portal vein) or cholangitis may cause this rare condition [50, 51].

Median UL Inflammation of the median UL is a so-called urachal abscess (Fig. 18). Variations in the patency of the urachal lumen determine the site of discharge (umbilicus, bladder, or both). Entero(-vesico-)urachal fistula can occur in Crohn's disease [52]. Migration of a fish bone can cause urachal abscess [53]. Chronic urachal infection (organizing urachal abscess) can mimic a neoplasm [54]. Surgical inter-

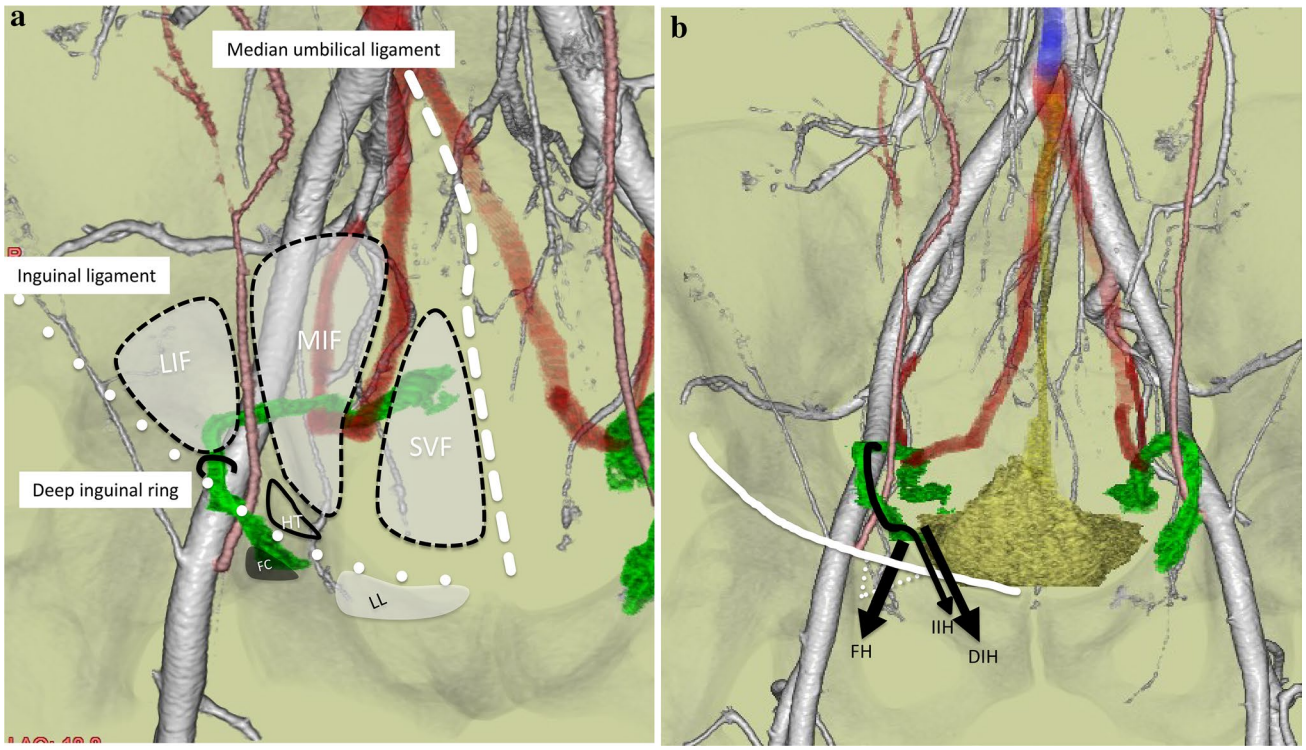

Fig. 8 Lower abdominal fossae defined by the umbilical ligaments and differentiation of groin hernias. **a** The ULs divide the lower abdominal wall into three fossae: the lateral inguinal fossa (LIF), medial inguinal fossa (MIF), and supravesical fossa (SVF). The femoral canal (FC), Hasselbach's triangle (HT), and deep inguinal canal are very close to each other. LL, lacunar ligament. **b** Three arrows indicate a direct inguinal hernia (DIH), an indirect inguinal hernia (IIH), and a femoral hernia (FH). The white line is the inguinal ligament, and the dotted line is the femoral canal. Note the relation to the inguinal canal and direction of the herniation. DIH and IIH are ventral to the ligament, while FH is dorsal to it

vention is recommended because of the high reinfection rate (30%) and risk of urachal carcinoma [10].

Medial ULs Only six cases of umbilical artery infection are found in a search of the PubMed database (Fig. 19) [55-57]. Two of them were caused by umbilical artery catheterization in the neonatal period [56, 57]. A combination of umbilical discharge and off-midline lower abdominal pain are characteristic symptoms. Fat stranding along the medial UL may be pathognomonic for this rare condition. It is important to identify the medial UL from the umbilicus to the internal iliac artery in thin-slice images.

Tumors and tumor-like conditions

Round ligament Tumors of the round ligament or tumors in the falciform ligament are very rare; only case reports are found in the literature. Mesenchymal tumors or germ cell tumors may arise from the round or falciform ligaments. Leiomyomas, leiomyosarcomas, lipomas, gastrointestinal stromal tumors, solitary fibrous tumors, angiofibromas, teratomas, endodermal sinus tumors (yolk sac tumors), paragangliomas, perivascular epithelioid cell tumors (PEComas), clear cell myomelanocytic tumors, malignant mesotheliomas, metastases, and cysts have been reported [58-72]. Hepatocellular carcinomas rarely invade the ligament as a portal vein tumor thrombus [73]. Metastasis to the umbilicus (Sister Mary Joseph's nodule) can occur through this ligament and medial ULs [74].

Median/medial/lateral ULs The most commonly described benign tumors of the urachus are adenomas and cystadenomas. Fibromas, fibromyomas, fibroadenomas, and hamartomas occur with less frequency [10]. In addition, inflammatory myofibroblastic tumors and malacoplakias have been reported [75, 76].

Malignancies of urachal origin are rare (< 1% of all bladder cancers). Mucin-producing adenocarcinomas (69%) and mucin-negative adenocarcinomas (15%) are common histological subtypes; urothelial, squamous, and sarcomatoid malignancies follow [10].

Urachal carcinoma is male predominant. The location of the tumor is diagnostic for urachal carcinoma. Because of its mucin-producing nature, calcification within the tumor is the key to diagnosing urachal carcinoma (Fig. 20) [77]. Urachal carcinoma may invade the neighboring colon [78].

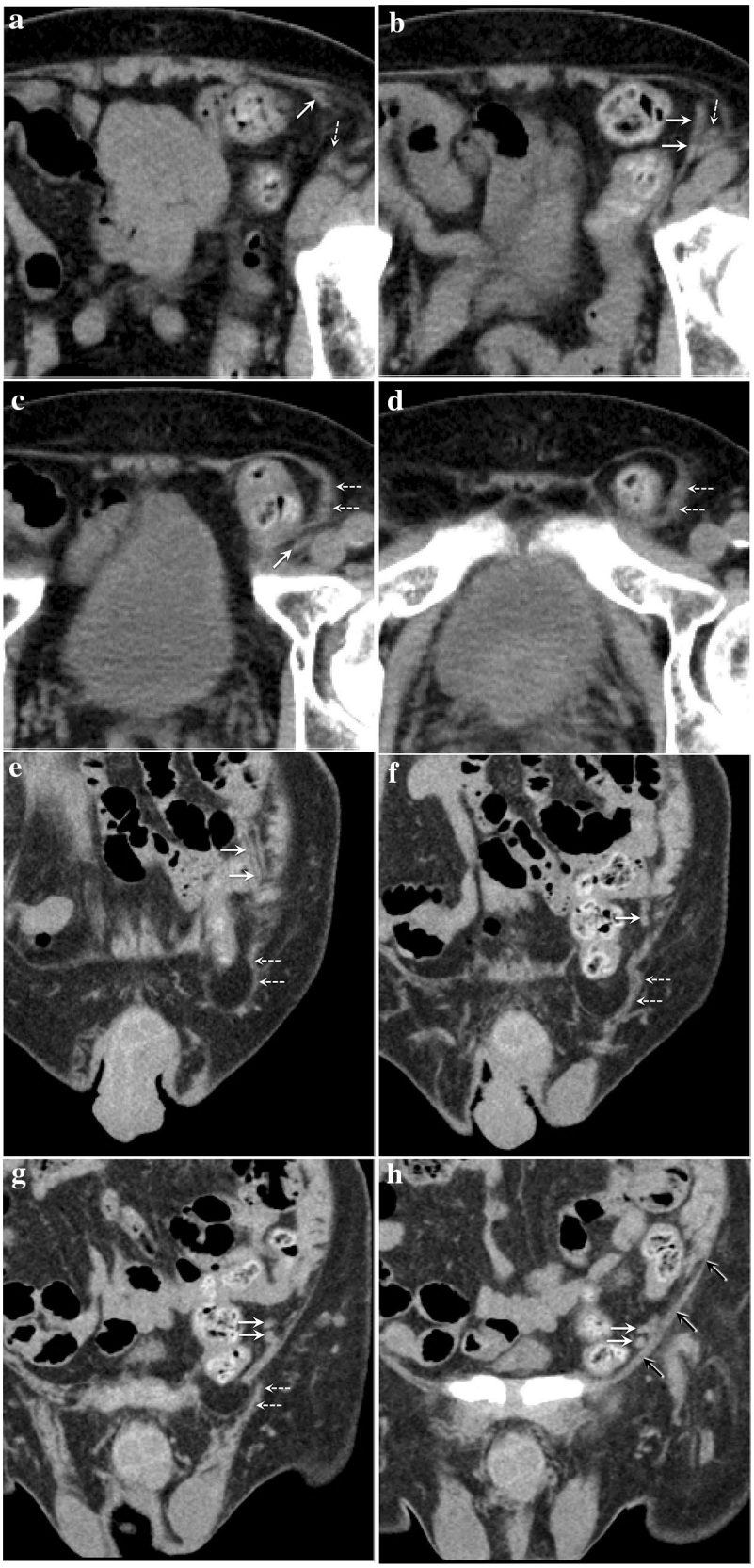

Fig. 9 Direct inguinal hernia (**a**–**d** axial images; **e**–**h** coronal images). A 77-year-old man with groin swelling is diagnosed with herniation of the sigmoid colon in the medial inguinal fossa (medial to the left lateral UL, indicated by white arrows). The contents of the inguinal canal (white dashed arrows) are displaced laterally (lateral crescent sign) by the herniated bowel. A compression deformity of the femoral vein is not noted. The herniation occurs over the left inguinal ligament (black arrows)

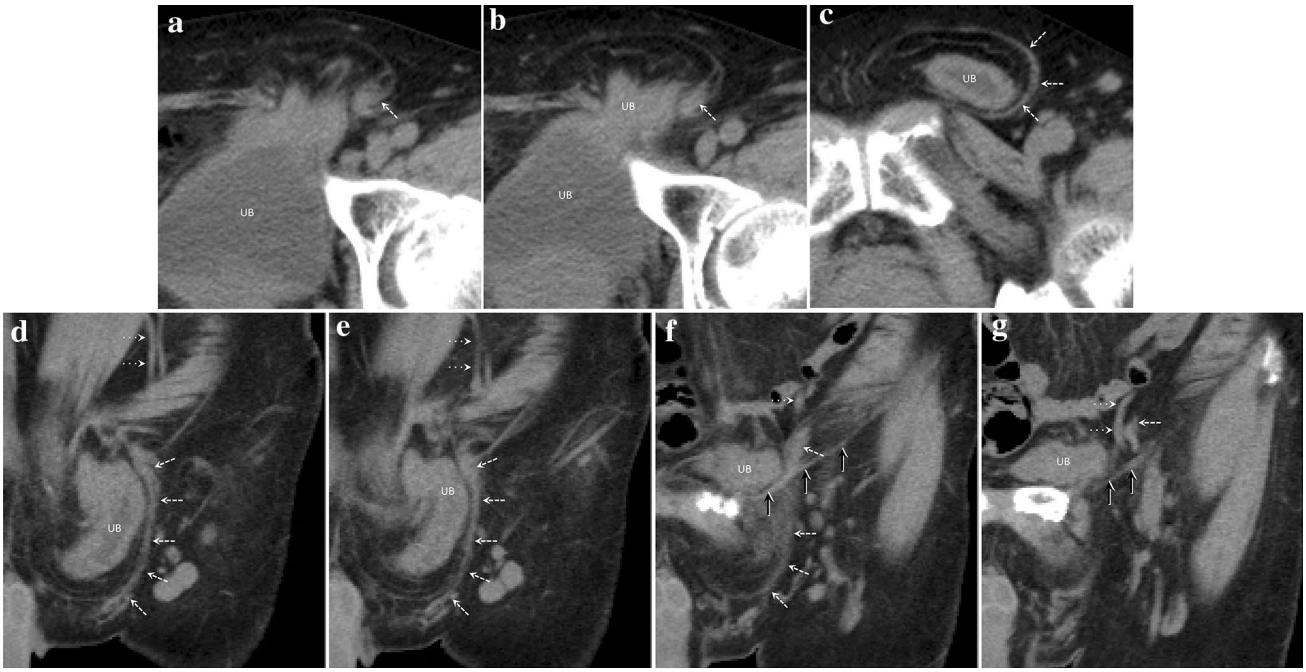

Fig. 10 Inguinal vesical hernia (direct) (**a**–**c** axial images; **d**–**g** coronal images). An 80-year-old man with left groin swelling; the urinary bladder (UB) is herniated into the left inguinal canal. Herniation occurs medial to the left lateral UL (white dotted arrows). The contents of the left inguinal canal (white dashed arrows) are displaced laterally. Black arrows indicate the inguinal ligament

To the best of our knowledge, there are no case reports describing tumors arising from the medial or lateral ULs.

Conclusions (four "fine" messages)

1. The round ligament of the liver should be carefully evaluated to identify RSRL before hepatobiliary surgery.
2. The median, medial, and lateral ULs are important clues to differentiate groin hernias.
3. Tumors and inflammation rarely involve the round ligament or median and medial ULs.
4. Radiologists should pay attention to these "fine" forgotten ligaments.

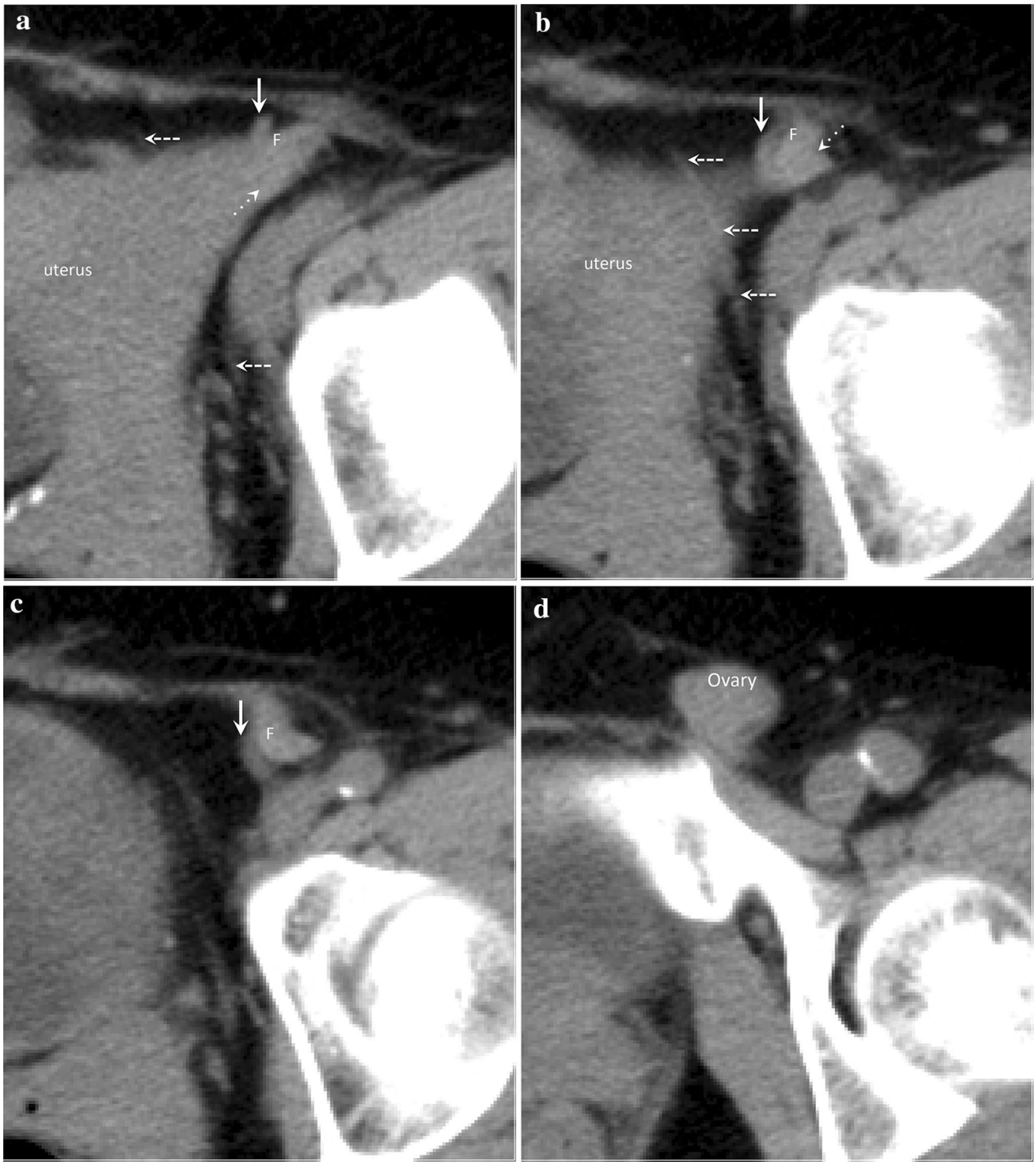

Fig. 11 Indirect inguinal hernia of the ovary (**a**–**d** axial images). A 68-year-old woman with a left groin nodule; the uterus is deviated to the left. The groin nodule connects to the suspensory ligament of the ovary (ovarian artery and vein, white dotted arrows). The medial UL (white dashed arrows), lateral UL (white arrows), and the fallopian tube and round ligament of the uterus (F)

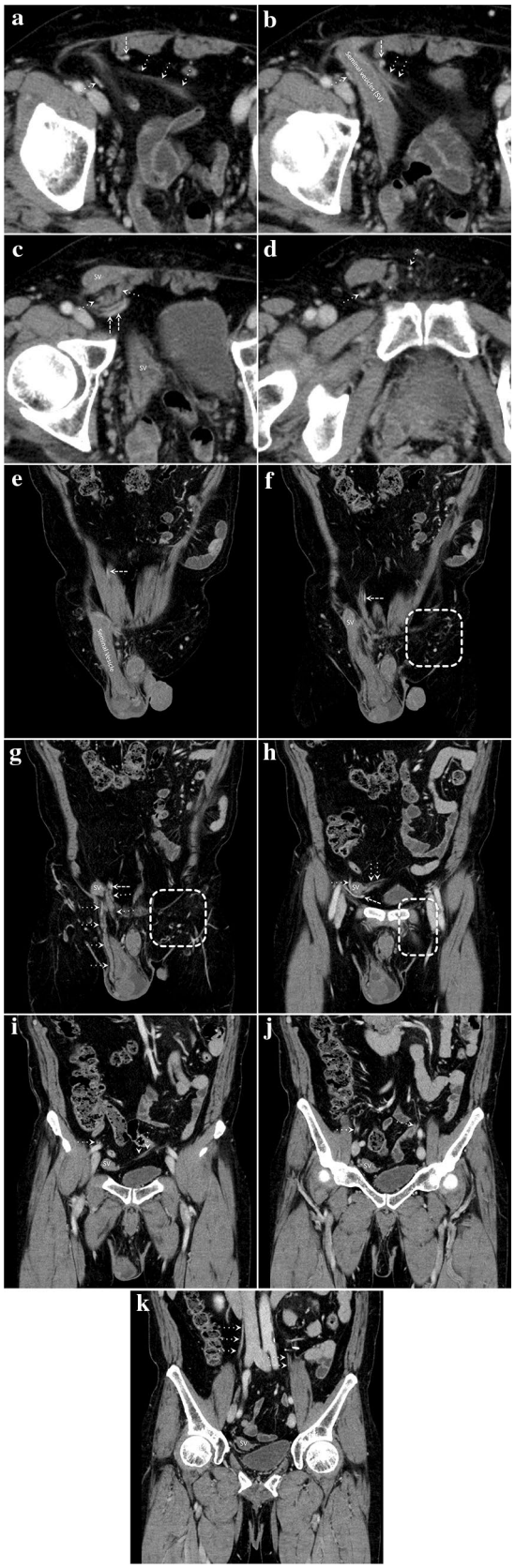

Fig. 12 Crossed testicular ectopia (**a**–**d** axial images; **e**–**k** coronal images). A 64-year-old man with right groin swelling; soft tissue in the right inguinal canal continues to both seminal vesicles (SV). White dotted arrows indicate the gonadal veins. The left inguinal canal contains no spermatic cord (dashed square). White dashed arrows indicate the right lateral UL

Fig. 13 Femoral hernia (**a**–**d** axial images; **e**–**h** coronal images). A 73-year-old woman with abdominal fullness and pain; the ileum is herniated caudal to the lateral UL (white arrows). The femoral vein (V) is compressed by the ileum. Compression of the femoral vein is not clearly seen on coronal images. The herniation is demonstrated posterior to the inguinal ligament (black arrows)

Fig. 14 Amyand's hernia (**a**–**d** axial images; **e**–**h** coronal images). A 74-year-old man with right groin swelling; the appendix (A) is herniated into the right inguinal canal lateral to the lateral UL (white arrows). Black arrows indicate the inguinal ligament

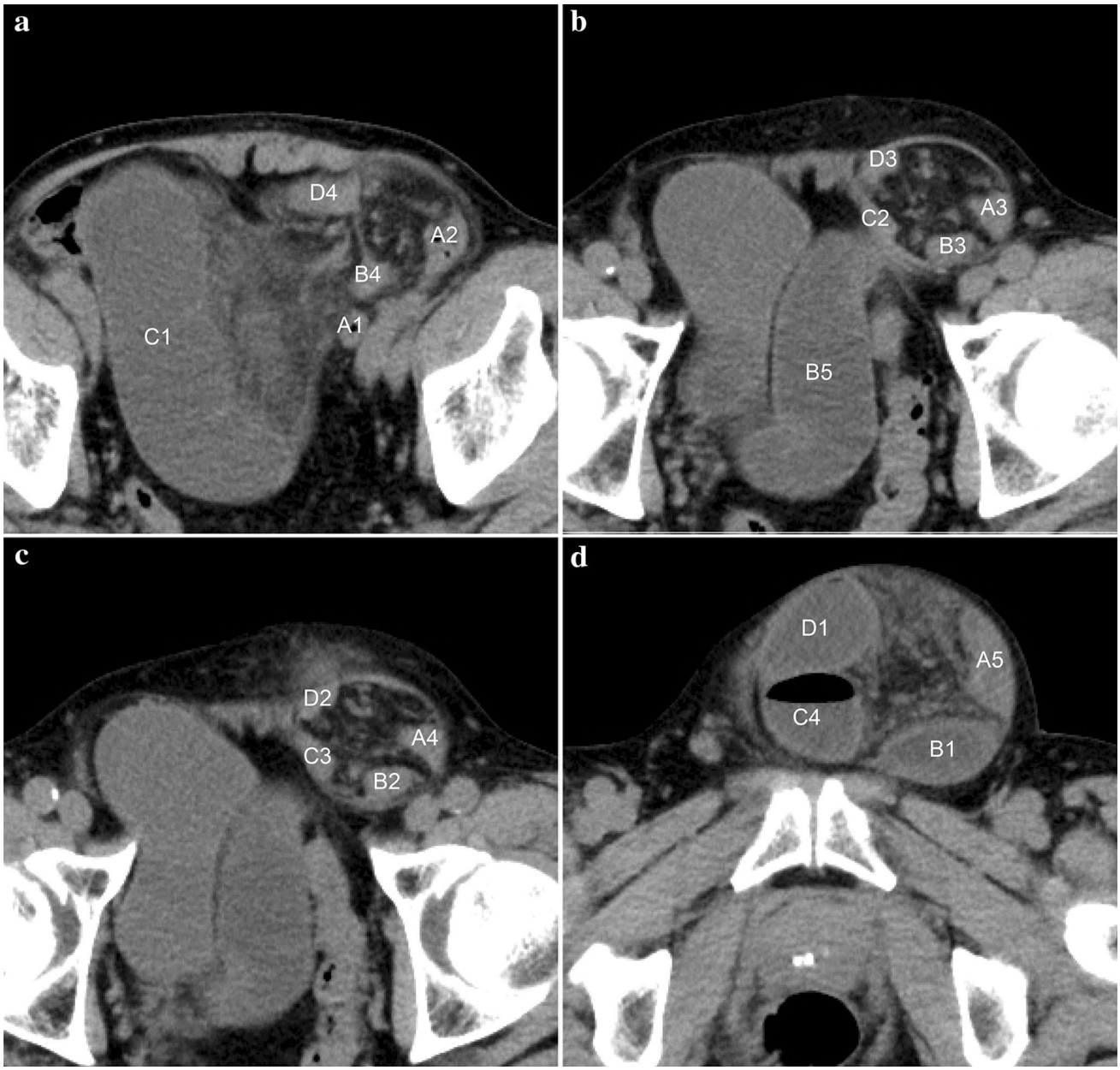

Fig. 15 Maydl's hernia (**a**–**d** axial images). A 75-year-old man with abdominal pain after failure of self-reduction; a left indirect inguinal hernia is seen. In the inguinal canal, four intestinal sections (A–D) are noted. A1–5, oral side; B1–5, partial reduction to the peritoneal cavity; C1–4, strangulated segment, back to the inguinal canal; D1–4, anal side

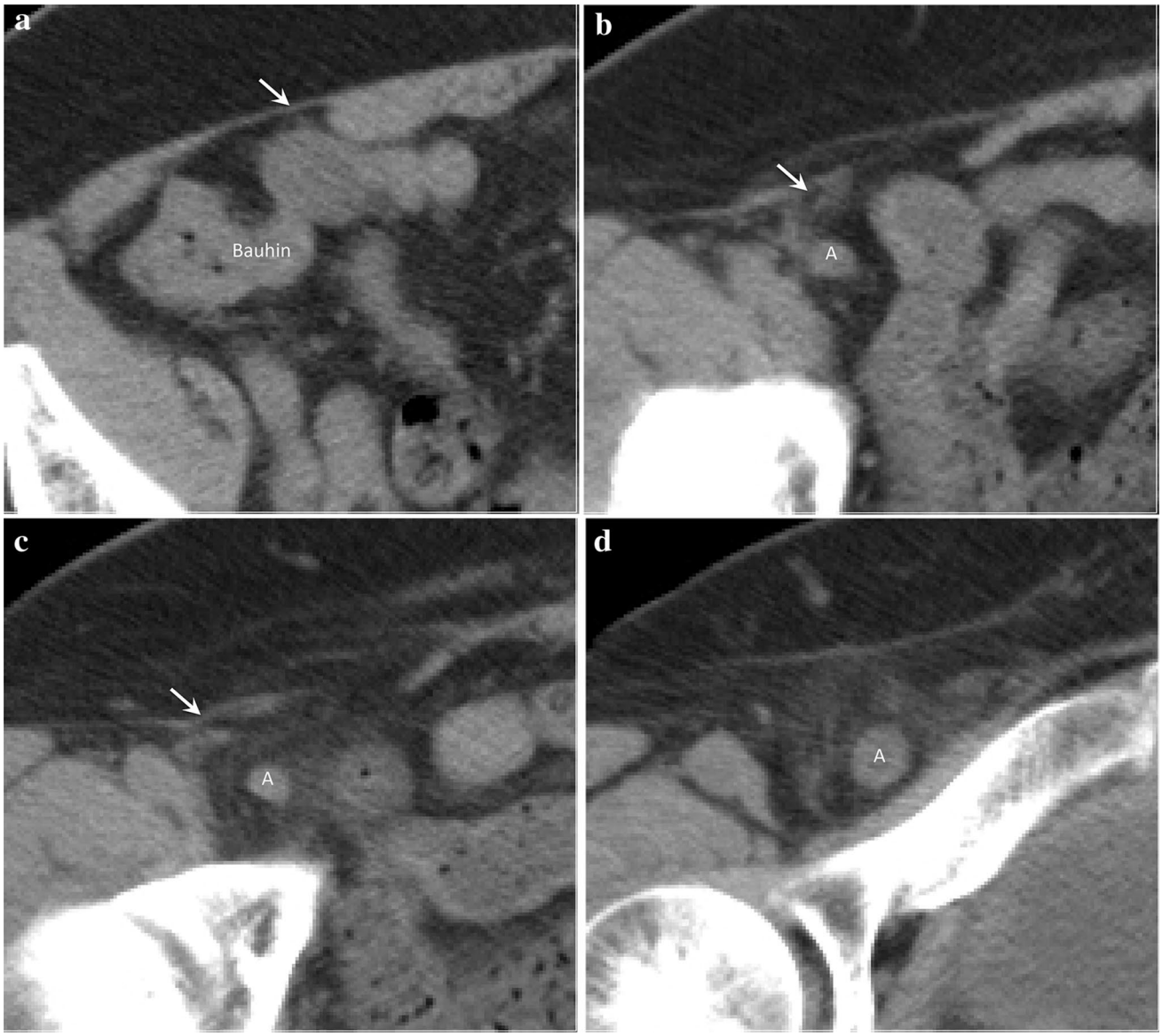

Fig. 16 de Garengeot's hernia (**a**–**d** axial images). A 72-year-old man with right inguinal swelling; the appendix (A) is herniated caudal to the lateral UL (white arrows). The right femoral vein is compressed and displaced laterally

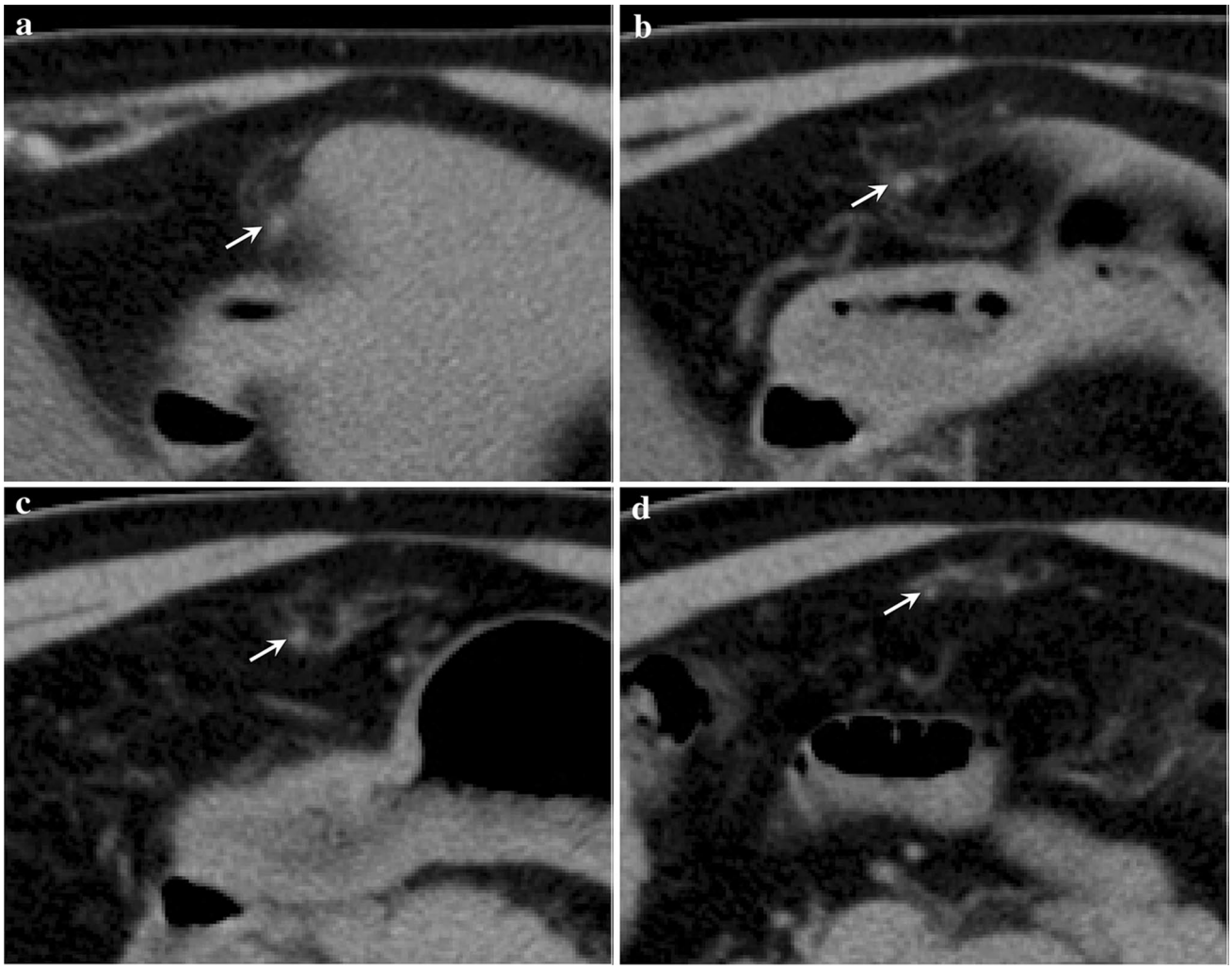

Fig. 17 Inflammation of the round ligament (**a**–**d** axial images). A 60-year-old man presented with fever and headache. Laboratory tests revealed C-reactive protein > 20.0 mg/L. CT demonstrates blurring of the round ligament of the liver (white arrows) and fat stranding around the ligament

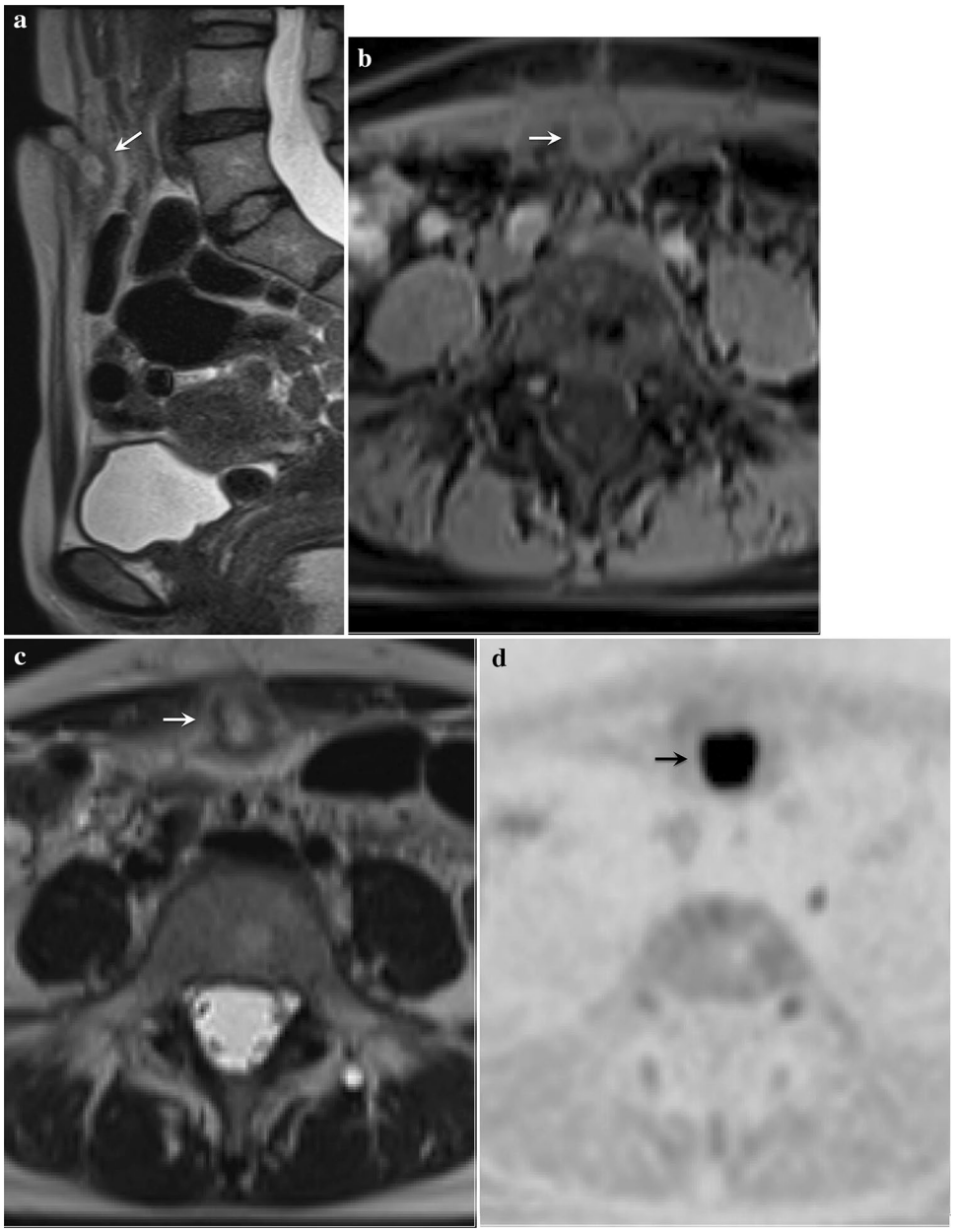

Fig. 18 Urachal abscess. A 45-year-old woman with umbilical discharge and fever underwent diagnostic studies. The sagittal T2-weighted image (**a**) demonstrates fluid in the urachal sinus. Contrast-enhanced T1-weighted image (**b**) demonstrates the well-enhanced thick wall of the urachal sinus. On the axial T2-weighted image (**c**), the wall of the urachal sinus shows low signal intensity. Restricted diffusion of the contents (**d**) and signal patterns of the urachal wall indicate an abscess

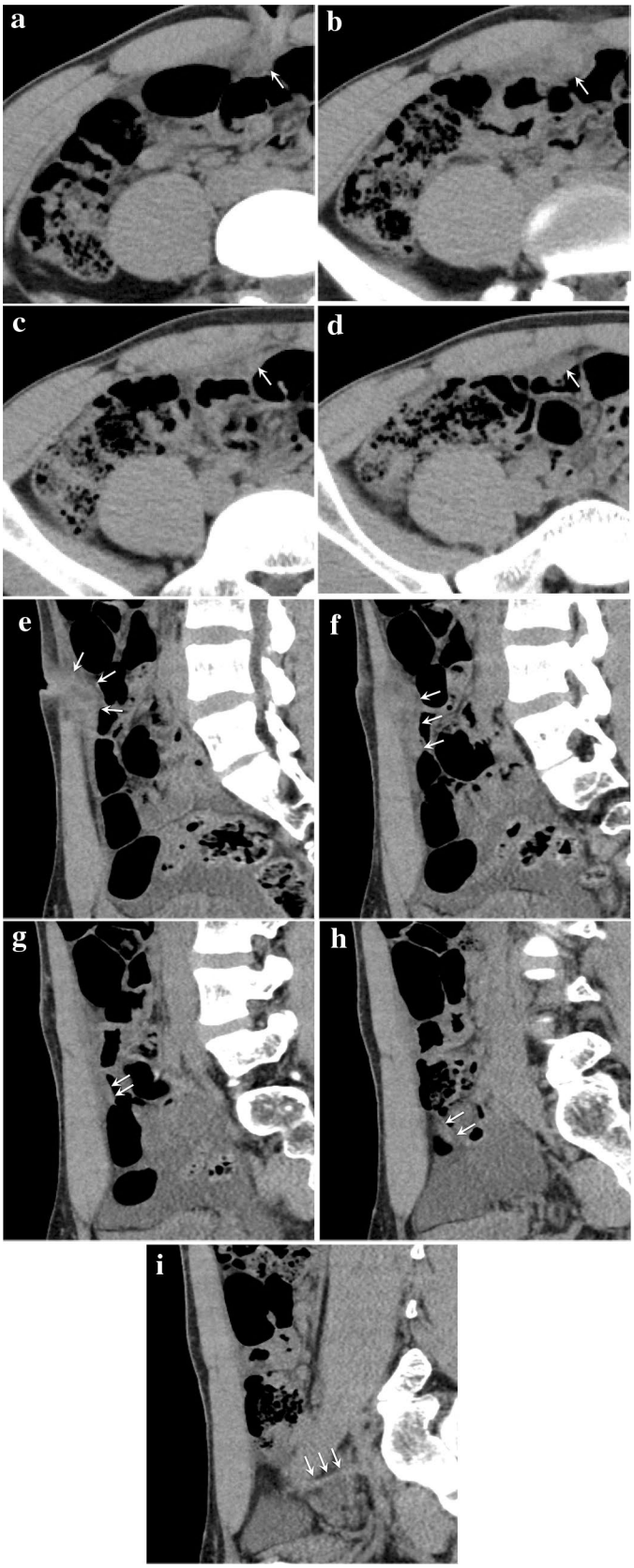

Fig. 19 Umbilical artery infection (**a**–**d** axial images; **e**–**i** sagittal images). A 19-year-old man with umbilical discharge and right lower abdominal pain; the umbilicus is swollen. There is fat stranding posterior to the right rectus abdominis muscle and inflammation along the medial UL (white arrows) is suspected. Fat stranding along the medial UL is clearly demonstrated on sagittal images

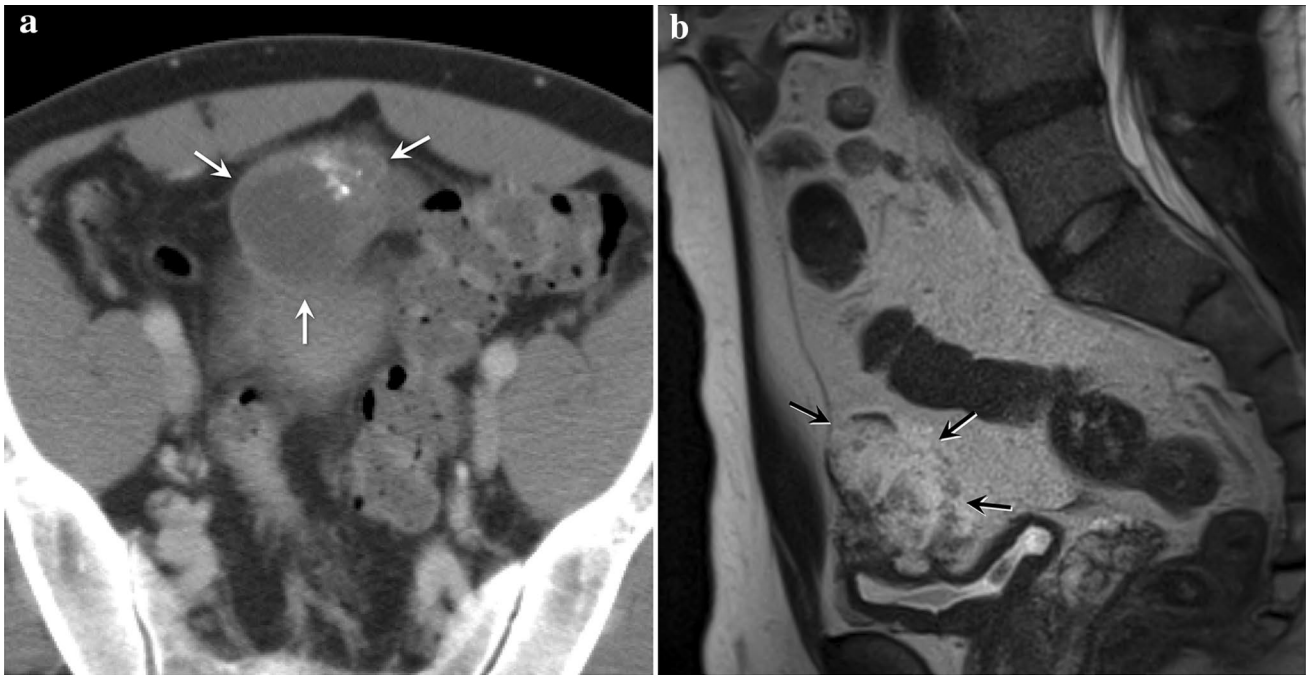

Fig. 20 Urachal carcinoma (**a** CT image; **b** MR image). An asymptomatic 45-year-old man undergoes an ultrasound study, with the incidental finding of a lower abdominal tumor. The tumor (white arrows), with calcification, is seen on CT. High signal intensity on the T2-weighted image indicates mucin production by the tumor (black arrows)

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Compliance with ethical standards

Conflict of interest The authors declare that there is no conflict of interest.

Ethical statement This manuscript is a review article and involves no studies with human participants or animals performed by any of the authors.

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