# Abdominal Wall Anatomy, Pathology, and Intervention

6

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## Abbreviations

| | |
|---|---|
| CT | Computed tomography |
| MRI | Magnetic resonance imaging |
| TAP | Transversus abdominis plane |
| US | Ultrasound |

## Introduction

Ultrasonography is an extremely useful diagnostic tool with increasingly sophisticated equipment and imaging capabilities. Modern ultrasound machines have many advantages that enhance their usefulness, such as handheld ultrasound devices, multifrequency transducers, color Doppler, and reusable biopsy guide attachments. Furthermore, the use of ultrasound (US) is especially pertinent in the era of rising health-care costs for it is a relatively inexpensive and safe technology. Its portability and accessibility allow for its real-time use in the ambulatory or operative setting, particularly when other modalities, such as computed tomography (CT) or magnetic resonance imaging (MRI), are not available or are contraindicated. US can be used for diagnostic purposes to identify and localize pathology and is extremely effective in guiding therapeutic interventions (e.g., draining intra-abdominal fluid collections or guiding laparoscopic trocar insertion).

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Ultrasound also plays a valuable role in the diagnosis and treatment of abdominal wall and groin pathology, especially as a first-line investigative modality. Surgeons quickly master and utilize ultrasonography for both diagnosis and intervention, given their technical background, their familiarity with the anatomy, and their ability to correlate the images to intraoperative findings. In this chapter, abdominal wall anatomy, pathology, and interventional ultrasound are reviewed.

## Ultrasound Instrumentation and Technique

Examination of the abdominal wall with US should be done in a systematic fashion. The entire abdomen should be examined prior to focusing on a particular area of pathology. The examination should begin cephalad at the subxiphoid process moving laterally and caudally through each compartment. A multifrequency transducer (7.5–12 MHz), which allows for high resolution at the cost of lower penetration, can be utilized. Either a curvilinear array or linear array transducer probe with color Doppler can be used to examine the abdomen and to identify and differentiate vascular structures, particularly in the preperitoneal space. Most machines will also allow for the capture of video and picture so that images may be stored for clinical documentation and educational purposes.

### Interventional Ultrasound Technique

Surgeons have utilized interventional ultrasound for decades as a diagnostic tool and to guide biopsies and drainage of fluid collections [1–3]. Since, it is an invasive procedure, it warrants a defined protocol; an informed consent from the patient must be obtained [4] and the patient should be advised on the low mortality and morbidity (less than 0.05 %) associated with interventional ultrasound [5]. A sterile environment should be maintained, including prepping and draping the patient's abdomen and ensuring that the ultrasound probe

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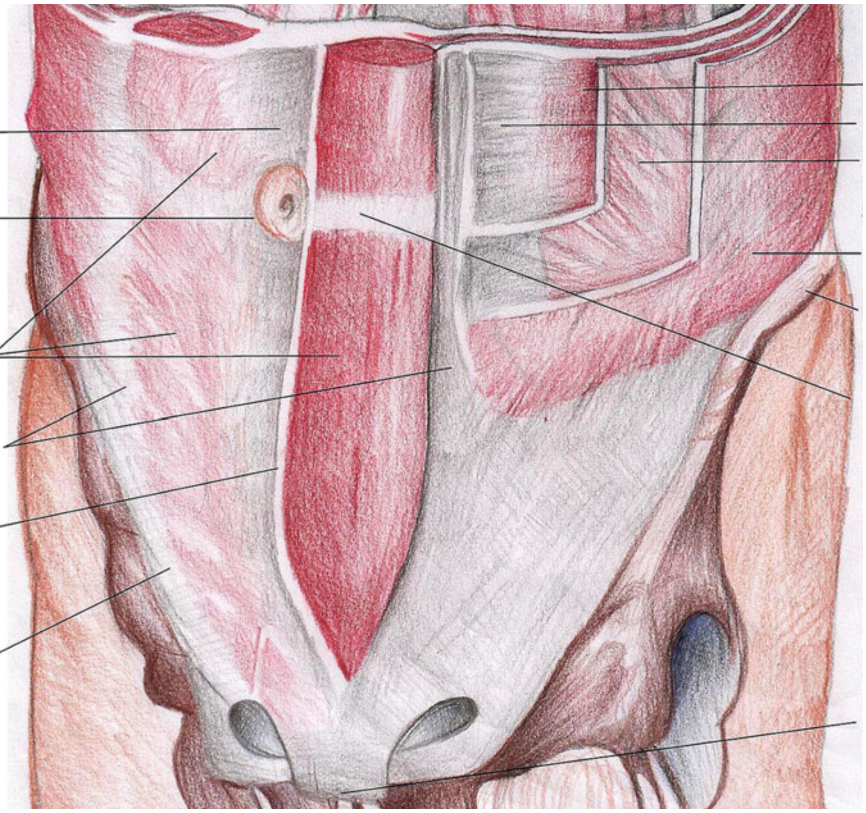


**Fig. 6.1** Anterior abdominal wall musculature and fascia

is dressed with a sterile transparent drape. Administration of local anesthesia and sedation may also be warranted.

In interventional ultrasound, either a freehand technique or a biopsy guide device can be used. An echogenic needle facilitates precise placement and access to the area of pathology. These needles have different lengths and biopsy sampling sizes, which are used based on the patient's body habitus and the location of the pathology to be sampled. For abdominal wall pathology, a needle with a length of 3–4 cm and caliber ranging from 14 to 23 gauge is employed depending on the intended purpose of the intervention; it is generally advisable to use the thinnest needle allowable. An 18–20 gauge needle is advisable when aspirating fluid collections, cysts, and abscesses. A smaller 22–23 gauge needle is sufficient when obtaining a cytology sample. A Menghini or an automatic biopsy needle (14–21 gauge) can be used for obtaining a tissue sample. An adjustable needle-steering device (12–20 gauge) can be used alternatively [1].

## Abdominal Wall Anatomy

### Anterior Abdominal Wall Musculature and Fascia

Examination of the abdominal wall by ultrasound requires knowledge of the abdominal wall anatomy. The anterolateral abdominal wall is composed of nine layers: skin, subcutaneous tissue, superficial fascia, external oblique muscles, internal oblique muscle, transversus abdominis muscle, transversalis fascia, preperitoneal tissue, and peritoneum (Fig. 6.1). Anteromedially, the rectus abdominis muscles replace the oblique and transversus muscles and lie within the rectus sheath. The midline of the abdomen is marked by the linea alba, which is a band of crisscrossing fibers extending from the xiphoid process to the pubic symphysis (Fig. 6.2). Separating the rectus abdomini muscles from the oblique and transversalis muscles laterally on each side is the linea semilunaris (Fig. 6.3). The linea semicircularis, also known as the arcuate line of the rectus sheath, is an anatomical line (that is not always clearly defined) along the inferior posterior rectus sheath marking a change in its composition (Table 6.1).

On ultrasound, the skin is echogenic and measures a couple of millimeters in thickness. The subcutaneous tissue will appear as oval hypoechoic nodules demarcated by echogenic septae. Interspaced within the tissue are perforating vessels. Below the subcutaneous layer lie the muscles and their investing fascia (Fig. 6.4). Inferiorly the external oblique aponeurosis curves inward on themselves to form the inguinal ligament (Poupart's ligament), which is the shelf of the inguinal canal. The internal oblique muscles lie posterior to the external oblique muscles. Also, in males, inferiorly, the

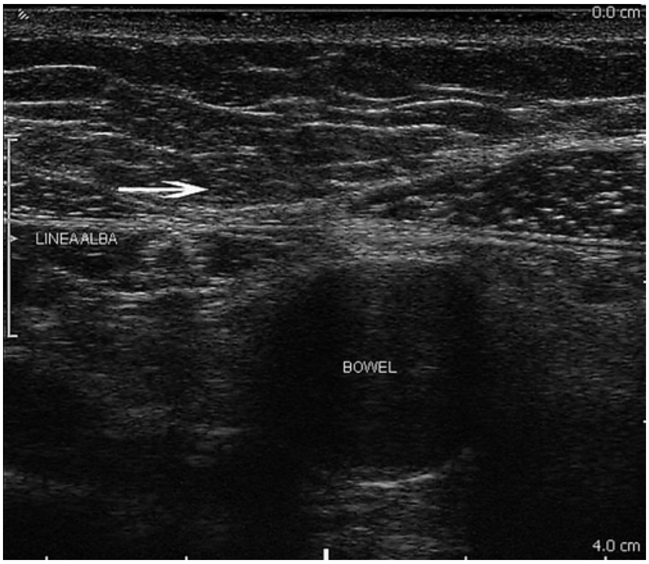


**Fig. 6.2** Abdominal wall anatomy at the abdominal midline. The linea alba is noted by the *arrow*

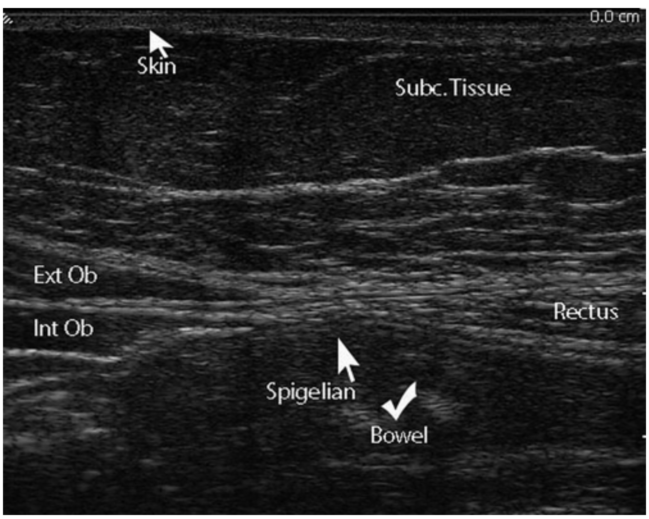


**Fig. 6.3** Linea semilunaris. The linea semilunaris along the lateral margin of the inferior rectus muscle is where a Spigelian hernia is expected to occur

**Table 6.1** Ultrasonographic appearance of abdominal wall anatomy

| Abdominal wall component | Sonographic features |
|---|---|
| Skin | Hyperechogenic |
| Subcutaneous tissue | Oval hypoechoic nodules demarcated by echogenic septae<br>Perforating vessels may be present |
| Fascia | Dense hyperechoic bands |
| Muscle | Intermediate echogenicity, echogenic dotting within each layer |
| Preperitoneal space | Hypoechoic adipose and areola tissue<br>Inferior and superior epigastric vessels visible with Doppler |

internal oblique aponeurosis fibers run alongside the spermatic cord to form the cremasteric muscles. The transversalis fascia lies posterior to the transversalis muscle and anteromedially forms the most posterior layer of the posterior rectus sheath prior to inserting at the linea alba. Medially, between the linea semilunaris and the linea alba lie the rectus abdominis muscles (Fig. 6.2). On ultrasound, the above muscle layers are of intermediate echogenicity and have echogenic dotting within each layer. The fascial layers separating the muscle layers appear as echogenic bands (Fig. 6.4).

## Preperitoneal Space and Peritoneum

The preperitoneal space lies deep to the abdominal wall muscle layers and the transversalis fascia. This space contains adipose and areolar tissue and includes the inferior and superior epigastric artery and vein and the umbilical ligaments. The medial umbilical ligament is the obliterated remnant of the fetal umbilical artery, and the median umbilical ligament is the remnant of the urachus, which persists as fibrous cord along the midline extending from the bladder to the umbilicus. Superior to the umbilicus and extending towards the liver is the falciform ligament. The ligamentum teres, also known as the round ligament, is the free margin of this falciform ligament and is the obliterated remnant of the umbilical vein coursing from the left portal vein to the umbilicus. The preperitoneal fat layer is a relatively thin layer measuring less than a cm in thickness on ultrasound.

## Vascular Supply of the Anterior Abdominal Wall

The inferior intercostal, lumbar, epigastric, and deep circumflex iliac arteries supply the arterial blood supply to the abdominal wall. The intercostal and lumbar arteries course alongside the nerves as bundles between the internal oblique and transversus abdominis muscles (Fig. 6.3). The superior epigastric artery is one of the terminal branches of the internal mammary artery and courses within the rectus sheath where it collateralizes with the inferior epigastric artery, which is a branch of the external iliac artery that courses superiorly in the preperitoneal space before piercing the rectus sheath. When imaging the abdominal wall with ultrasonography, it is important to identify the vessels in this preperitoneal layer prior to proceeding with any invasive intervention (Fig. 6.5a, b). The lymphatic drainage of abdominal wall is also similar to the venous outflow system whereby the supraumbilical lymph channels ultimately drain into the axillary basin while the infraumbilical channels drain into the superficial inguinal nodes. The lymphatic vessels from the liver also communicate with the periumbilical lymphatics via the ligamentum teres.

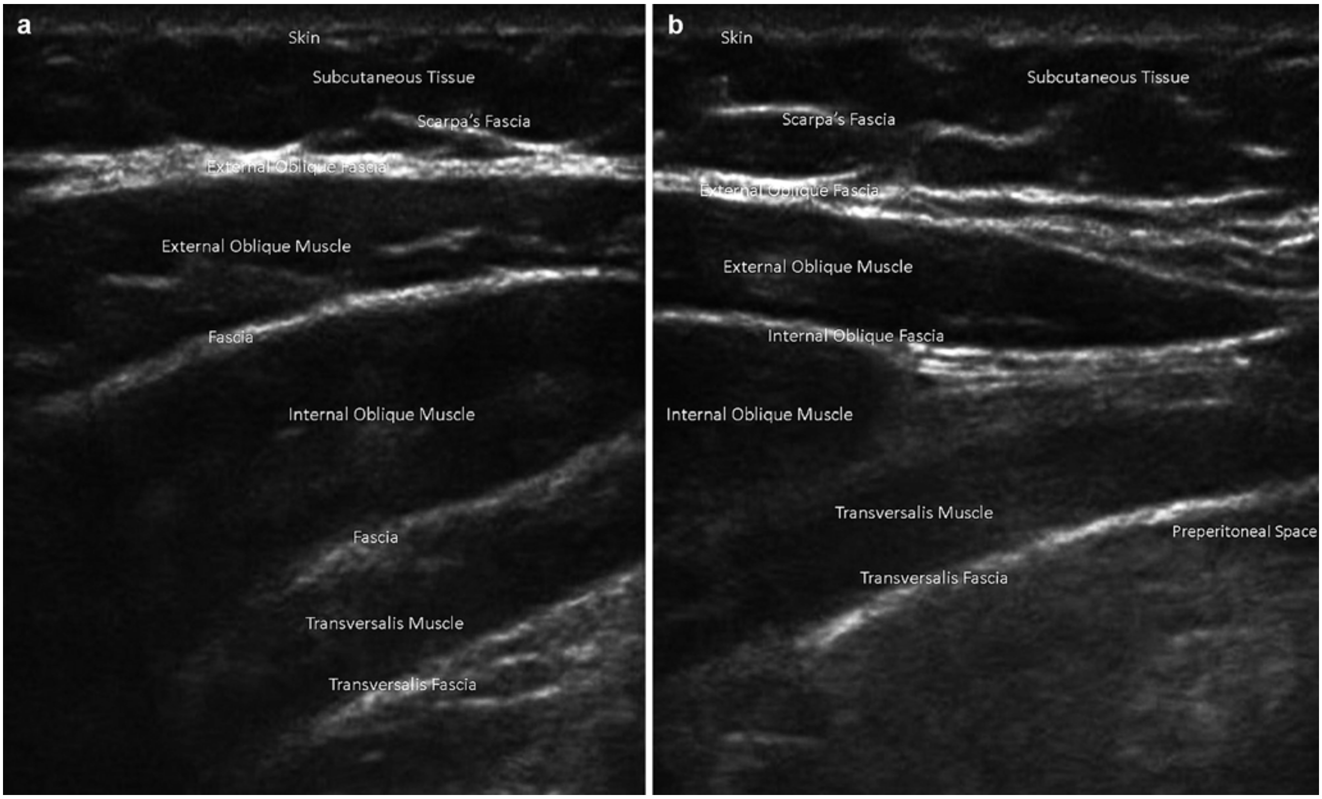


**Fig. 6.4** Abdominal wall muscles and fascia on ultrasound. (**a**) Lateral abdominal wall. (**b**) Medial abdominal wall, lateral to linea semilunaris

## Abdominal Wall Pathology and Intervention

A thorough physical examination will identify most pathological conditions within the abdominal wall. However, patient body habitus, edema, or complex masses can present a diagnostic dilemma for the clinician. US serves as a first-line tool in the identification, characterization, and management of abdominal wall pathology. Most pathology of the abdominal wall presents as a mass that may or may not be associated with skin changes. Ultrasound can further discern characteristics of the mass (solid versus cystic, complex versus simple, border regularity, etc.) as well as its location to the abdominal cavity and relationship to other abdominal wall structures. It is especially valuable in difficult-to-examine patients that are obese or comatose (Fig. 6.6). An image-guided biopsy using a #22 gauge needle or a #14 core biopsy can accurately and safely make a diagnosis after initial physical examination and ultrasound imaging [6, 7].

In this section, we review abdominal wall pathology and discuss US-guided interventions (Table 6.2).

### Rectus Diastasis

Rectus diastasis is characterized by a thinning of the linea alba so that the distance between the rectus muscles is increased. There is no defect in the underlying aponeurosis and transversalis fascia; thus, there is no actual hernia. The patient may have a midline bulge as a result of this diastasis that is often mistaken as a hernia (Fig. 6.2). Management usually entails reassurance to the patient. If surgical correction is desired by the patient, abdominoplasty techniques are utilized. Ultrasound has been shown to be an accurate method of measuring the supraumbilical and periumbilical diastasis for the purposes of operative planning [8].

### Rectus Sheath Hematomas

Hematomas within the rectus sheath are uncommon. They may develop spontaneously, yet, they often are associated with traumatic injury, pregnancy, coughing, or the use of anticoagulation therapy. They present with an acute onset of abdominal pain and tenderness that may be mistaken for peritonitis. In advanced cases, there may also be periumbilical or flank ecchymosis. Abdominal ultrasonography and CT scan aid in identifying the extent of a hematoma. The sonographic appearance of a rectus sheath hematoma varies with the age and location of the hematoma (Fig. 6.7). Above the arcuate line, the hematoma will have a lens-shaped appearance, whereas below the arcuate line, it may be more extensive, even crossing the midline or compressing the bladder [1].

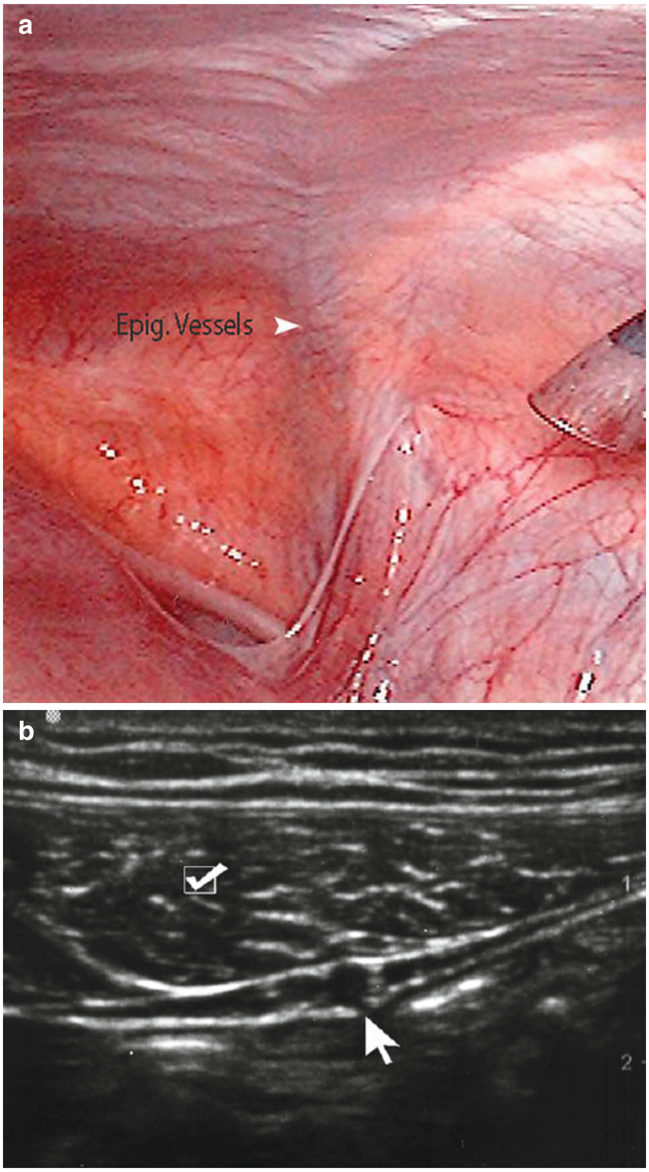


**Fig. 6.5** (**a**) Note epigastric vessels through laparoscopic view. (**b**) Ultrasound imaging of epigastric vessels (*arrow*) and rectus abdominis muscle (*checkmark*)

Hematomas are primarily hypoechoic but can have septal or cystic components with echogenic borders [9]. Varying echogenicities within the hematoma represent different states of organized clot formation [10, 11]. Acute hematomas are homogenous and echogenic, while late-stage hematomas can be anechoic [10].

Management is usually conservative involving bed rest, analgesics, correction of coagulopathies, and blood transfusions as needed. If persistent bleeding is suspected, angiographic embolization of the bleeding of the vessel may be warranted, and if this is not available or successful, operative hemostasis and hematoma evacuation may be necessitated. Ultrasonography can be utilized to screen for hematomas

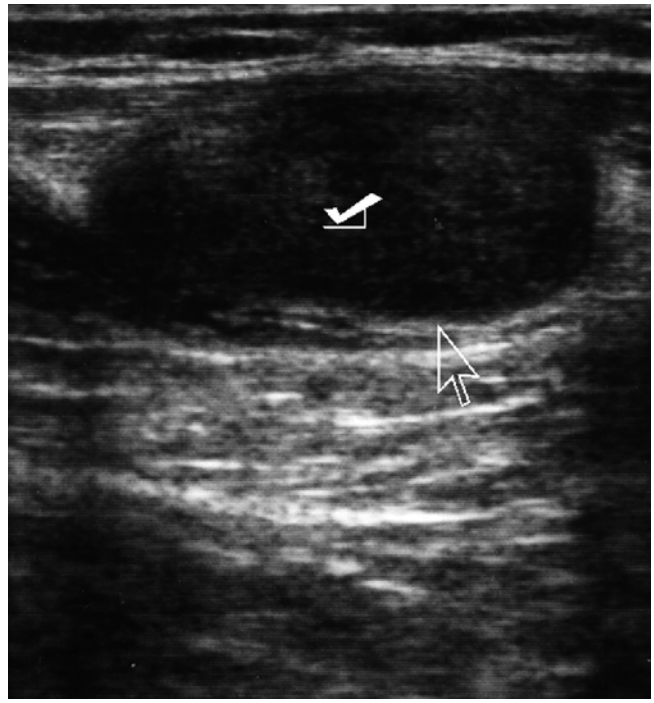

**Fig. 6.6** Ultrasound of the abdominal wall depicting tumor implant (*check mark*). *Arrow* points to interface between tumor and wall

**Table 6.2** Ultrasonographic appearance of abdominal wall masses

| Abdominal wall pathology | Sonographic features |
|---|---|
| Rectus sheath hematoma | Primary hypoechoic but varies with age and location of the hematoma<br>Acute hematomas are homogenous and echogenic while late-stage hematomas can be anechoic<br>Above the arcuate line: lens-shaped appearance<br>Below the arcuate line: more extensive and may cross midline |
| Hematoma | Variable echogenicity<br>Acutely hyperechoic |
| Seroma/cyst | Simple fluid: anechoic, homogeneous appearance, posterior enhancement<br>Complex: anechoic and hyper-/hypoechoic, heterogeneous |
| Abscess | Echogenic rim enhancement<br>Variable echogenicity within cavity with presence of debris and septations |
| Urachal cyst | Well-circumscribed fluid collections<br>Located along the lower midline<br>Anechoic<br>Varying internal echogenicity when infected with associated adjacent soft-tissue stranding |
| Abdominal wall varices | Dilated veins visible with Doppler<br>Recanalized umbilical vein is anechoic in background of fatty falciform ligament |
| Endometriosis | Irregular hypoechoic mass<br>Scattered internal echoes and internal vascularity |

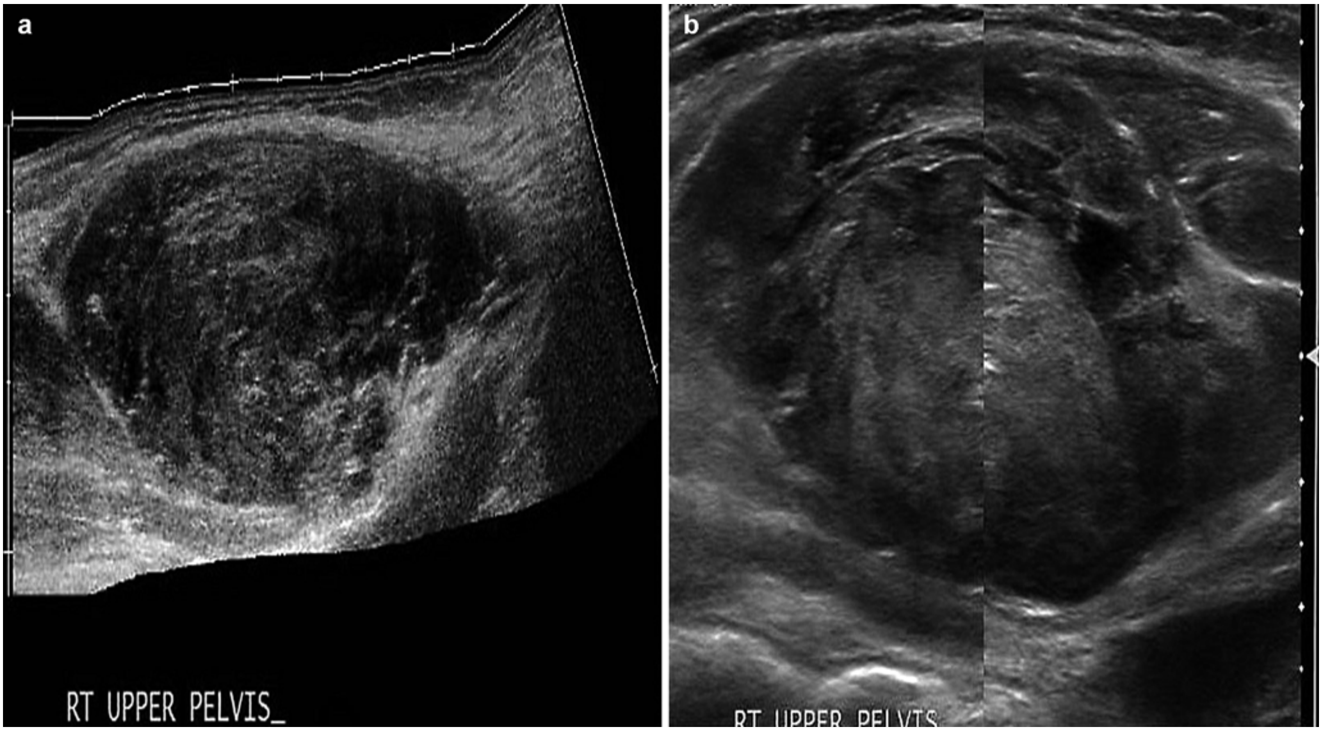


**Fig. 6.7** Rectus sheath hematoma. (**a**) Rectus sheath hematoma below the arcuate line, with varying stages of echogenicity. (**b**) Acute-stage rectus sheath hematoma, with early organized clot formation (hyperechoic)

that may require surgical intervention. Hematomas that are larger in diameter and demonstrate the presence of intra-abdominal free fluid on ultrasound are more likely to benefit from surgical exploration [12]. Ultrasonographic treatment of rectus sheath hematomas, where repeated sessions of non-thermal pulsed sonography are employed, has also been reported in the physical therapy literature [13].

## Abdominal Wall Fluid Collections

Abdominal wall fluid collections include cysts, hematomas, seromas, and abscesses. Ultrasonography is a useful modality in identifying a fluid collection and its characteristics. Hematomas may be spontaneous, postsurgical, or related to anticoagulation therapy or traumatic injury. If warranted, hematomas may be drained with image guidance. Abscesses have a variable appearance on ultrasound. They are typically irregular fluid collections containing septations and fluid debris and may have air-fluid levels (Fig. 6.8). They may also exhibit peripheral hyperemia with Doppler evaluation [10]. If gas bubbles are present with the abscess, they will be echogenic and demonstrate acoustic shadowing [14]. Seromas are usually more homogenous anechoic or hypoechoic fluid collections on ultrasound (Fig. 6.9). They are usually encountered following an abdominal operation, particularly following ventral hernia repairs. The development of postoperative seromas may be prevented with the use of pressure dressings and abdominal binders. If there is no evidence of superinfection, it is acceptable to observe a seroma without intervention, as there is a risk of introducing infection with needle aspiration. If a seroma or hematoma appears infected or an abdominal wall abscess is identified, operative drainage or needle drainage with image guidance is warranted in addition to antibiotic therapy. For larger fluid collections that are percutaneously drained, a drain may be left in place to facilitate additional drainage (Figs. 6.10 and 6.11).

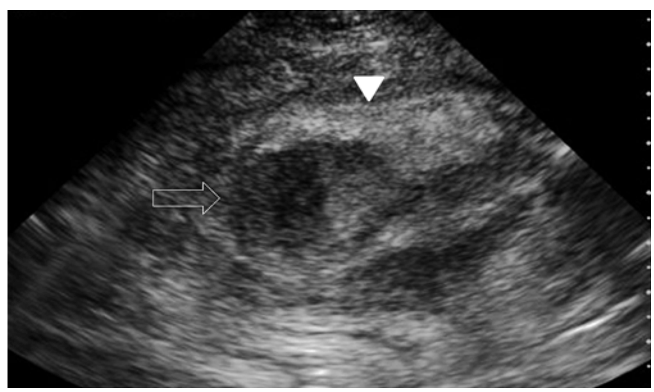

**Fig. 6.8** Abdominal wall abscess (*solid arrow*). Abscess at umbilical incision site following laparoscopic appendectomy. Echogenic rim enhancement is seen. The abscess cavity demonstrates varying echogenicities with debris


**Fig. 6.9** Postoperative seroma. Anechoic fluid collection near umbilical incision consistent with postoperative seroma

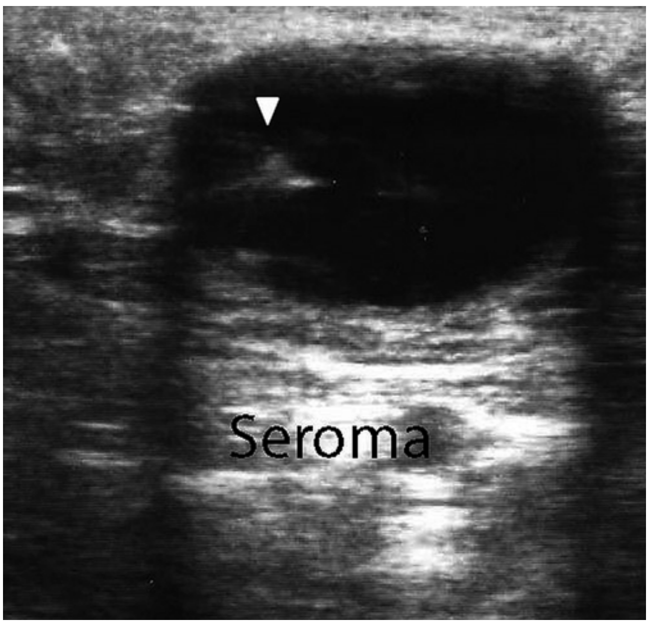


**Fig. 6.10** Postoperative abdominal wall mass representing a seroma with enhancement. Note needle within the seroma (*arrowhead*)

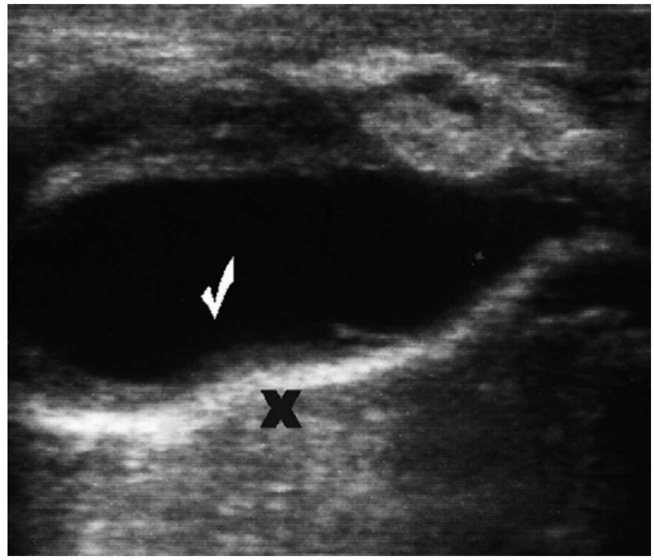


**Fig. 6.11** Postoperative seroma (*checkmark*) following repair of ventral hernia. Note mesh (*X*)

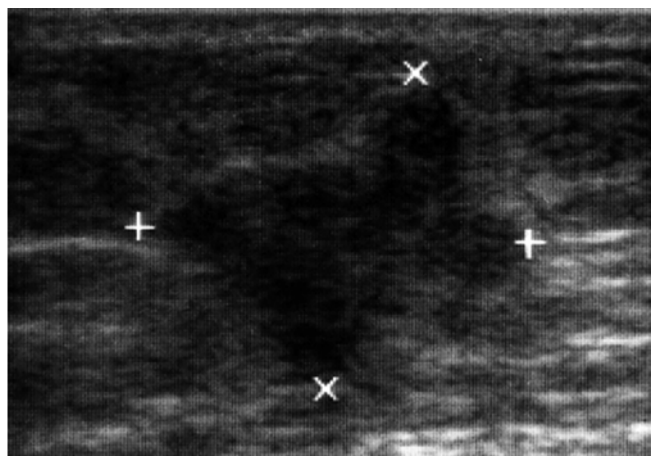

**Fig. 6.12** Metastatic nodule in the abdominal wall following a resection for retroperitoneal sarcoma. The axis of the tumor (+, ×)

## Abdominal Wall Neoplasms

Abdominal wall neoplasms present as painless palpable masses. Primary lesions may arise from any of the abdominal wall components: connective tissue, muscle, fat, blood vessels, or lymphoid tissue. These include benign soft-tissue neoplasms such as lipomas and desmoid tumors as well as malignant neoplasms such as sarcomas. Desmoid tumors and sarcomas are the most common primary malignancies of the abdominal wall. Metastatic neoplastic lesions may also be found in the abdominal wall, which often is associated with transperitoneal seeding of the abdominal wall by intra-abdominal malignancies (Fig. 6.12). Ultrasound examination permits precise definition of the mass as well as accurate biopsy. A diagnostic dilemma frequently occurs with these incisional wall masses where a recurrent tumor implant, a hernia, or a fluid collection could be found (Fig. 6.13). Ultrasound guidance is of value in obtaining a diagnostic biopsy of small nodules in the abdominal wall that are concerning for metastases (Table 6.3).

## Benign Tumors

Lipomas, neurofibromas, and hemangiomas are the most common benign neoplasms of the abdominal wall. Lipomas are well-circumscribed mobile lesions. On ultrasound, they will have a variable echogenicity that is discrete from the

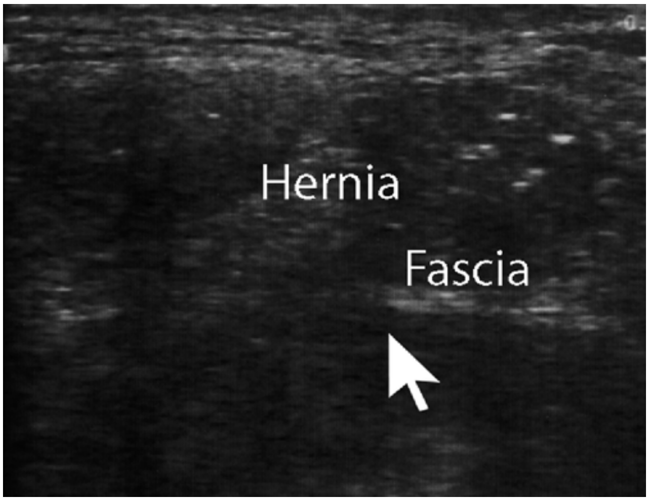


**Fig. 6.13** Postoperative incisional hernia with incarcerated bowel

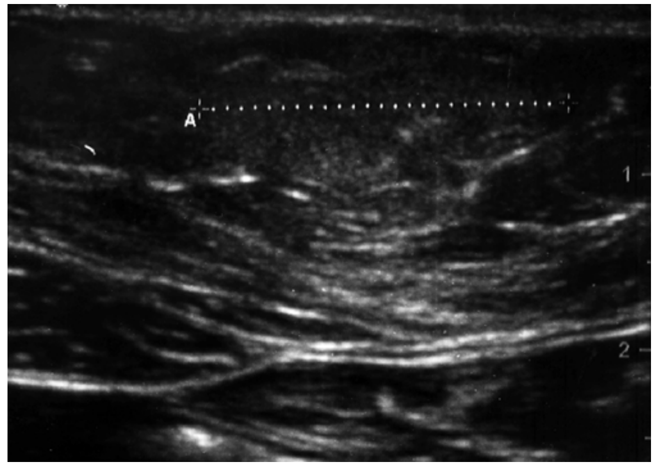

**Fig. 6.14** Subcutaneous abdominal wall lipoma. Notice the smooth border and isoechoic content. Lipomas could present with bilateral or unilateral shadows

**Table 6.3** Ultrasonographic appearance of abdominal wall tumors

| Abdominal wall pathology | Sonographic features |
|---|---|
| Lipoma | Variable echogenicity that is discrete from the surrounding fat and muscle |
| | May have an echogenic capsule |
| Hemangioma | Multiple hypoechoic or anechoic cystic areas within an echogenic hypervascular background |
| Desmoid tumor | Solid |
| | Hypoechoic |
| | Abutting fascial planes or muscular tissue |
| Sarcomas | Irregular |
| | Solid |
| | Hypoechoic |
| | May have localized areas of necrosis or fluid |
| Metastatic lesions | Irregular |
| | Hyperechoic |
| | Irregular shadow |

surrounding fat and muscle, and they may have an echogenic capsule [15] (Fig. 6.14). Hemangiomas are typically very small in diameter (millimeters) and on ultrasound will have multiple hypoechoic or anechoic cystic areas within an echogenic hypervascular background [10].

## Desmoid Tumor

Desmoid tumors, or *aggressive fibromatosis*, are rare neoplasms that arise from fibroblast cells in either fascia or muscle. They may be intra-abdominal (pelvic and mesenteric), extra-abdominal (shoulder girdle or extremities), or abdominal wall tumors. When the tumor is superficial, it arises from the fascia and typically is slow growing in nature and of small size. These lesions are commonly referred to as *Dupuytren's fibromatosis*. Deeper lesions arise from the musculoaponeurotic tissues and are usually more aggressive in growth rate and size. Although these tumors do not metastasize and are thus considered benign lesions, they are locally aggressive and often recur following resection.

Additional characteristics of the mass and the extent of involvement may be delineated with the use of an ultrasound. If the lesion is solid, hypoechoic, and abutting fascial planes or muscular tissue, one should be suspicious for a desmoid lesion. If an ultrasound is inadequate, further extent of the lesion may be defined with the use of MRI. The lesion requires biopsy for diagnosis, which may be obtained with a core needle or as an incisional biopsy under ultrasound guidance.

The treatment of abdominal wall desmoids involves surgical resection with tumor-free margins. Local recurrence rate of these tumors can be as high as 40 % [16], and these recurrent tumors will also require resection. If a lesion is unresectable, primary radiation treatment may be considered as well as palliative chemotherapy with antiproliferative cytotoxic agents.

## Sarcoma

The most common primary malignant neoplasm involving the abdominal wall is a sarcoma. These sarcomas, depending on what layers and cell types of the abdominal wall soft tissue are involved, can be of several subtypes: liposarcoma, fibrosarcoma, leiomyosarcoma, rhabdomyosarcoma, and malignant fibrous histiocytoma. The clinical progression of these tumors is reflective of their histology, size, and location.

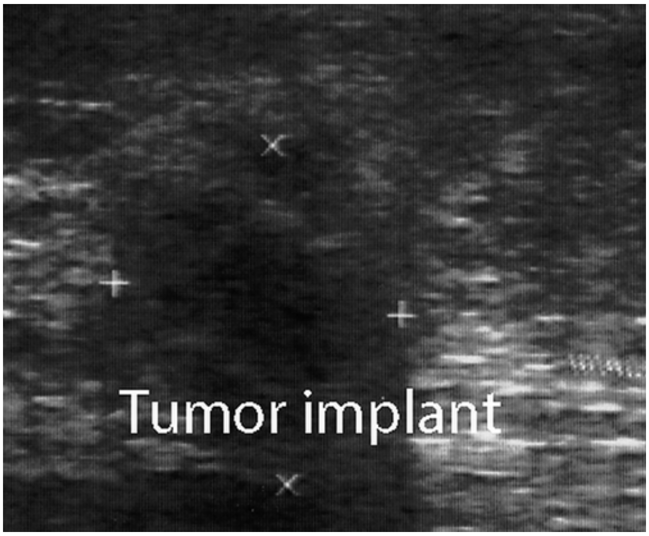


**Fig. 6.15** Abdominal wall tumor implant in a patient with a history of colon cancer. The axis of the tumor (+, ×)

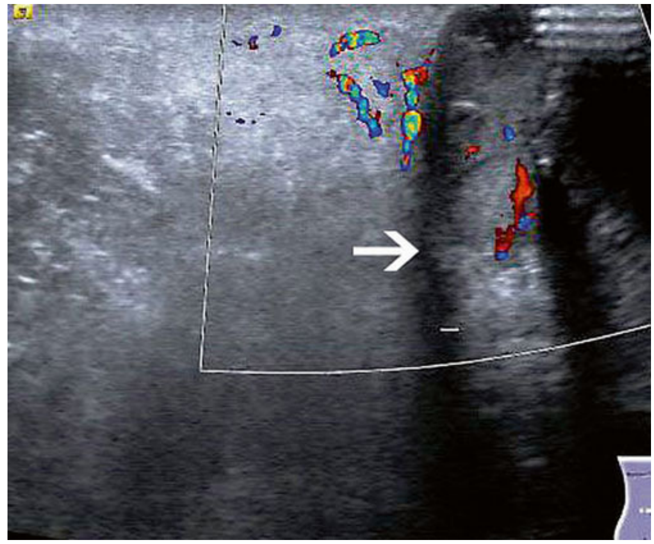

**Fig. 6.16** Infected infraumbilical abdominal wall urachal cyst (*arrow* points at cyst wall)

These abdominal wall sarcomas can present as painless abdominal wall masses. Suspicion for malignancy arises with masses that are solid, large, fixated, and fast growing. On ultrasound, a sarcomatous lesion will be a hypoechoic solid lesion that may have localized areas of necrosis or fluid [10]. MRI can also be used to further delineate extent of disease. These lesions require guided biopsies, either incisional or percutaneous, to confirm their pathological diagnosis.

### Metastatic Neoplasm

Transperitoneal, hematogenous, lymphatic seeding of intra-abdominal carcinomas or melanomas may result in metastatic lesions in the abdominal wall (Fig. 6.15). Cases of port-site seeding after laparoscopic surgery have also been reported in the literature, particularly following laparoscopic cholecystectomy where the cancer diagnosis was unknown at the time of operation. A metastatic deposit at the umbilicus is known as a Sister Mary Joseph's nodule. These lesions may be characterized and biopsied with sonographic guidance and are typically treated with surgical resection and radiation as needed. Ultrasound has also been reported to be of use in guiding insertion of applicator needles that can administer brachytherapy to abdominal wall metastases from colorectal cancer [17].

### Other Abdominal Wall Masses

#### Urachal Cyst

An urachal cyst is a sinus remnant that persists between the umbilicus and bladder. It is usually present in the lower third of the urachus but may lie inferior to the umbilicus as well. These cysts can be depicted on ultrasound, where there will be well-circumscribed fluid collections that are anechoic, along the lower midline [15]. When infected, they have varying internal echoes and may be associated with adjacent soft-tissue inflammatory changes and urinary bladder wall thickening on ultrasound [18]. If symptomatic or associated with recurrent urinary tracts infections, these cysts should be surgically excised (Fig. 6.16).

#### Vascular Anomalies

Patients with portal hypertension often recannulate their umbilical vein as a means to shunt blood flow to the systemic veins (caput medusae). Ultrasound with color Doppler can be utilized as a means to avoid these varices when performing abdominal wall procedures such as a paracentesis or placement of a percutaneous endoscopic gastrotomy tube in patients with portal hypertension (e.g., cirrhotic patients) [19].

#### Scar-Related Masses

Common masses that present in relation to prior surgical scars include stitch granulomas, heterotropic calcifications, and endometrial implants. A stitch granuloma will occur near a retained nonabsorbable suture and will demonstrate irregular borders and heterogenicity on ultrasound. Heterotrophic calcifications are benign lesions, which on US examination have posterior acoustic shadowing [10]. Endometriosis of the abdominal wall may occur following a prior gynecologic operation. It is the most common site of extraovarian or extrauterine endometriosis following a cesarean section operation [20]. The lesion may present as a painful solid mass near a previous scar. On ultrasonography, it

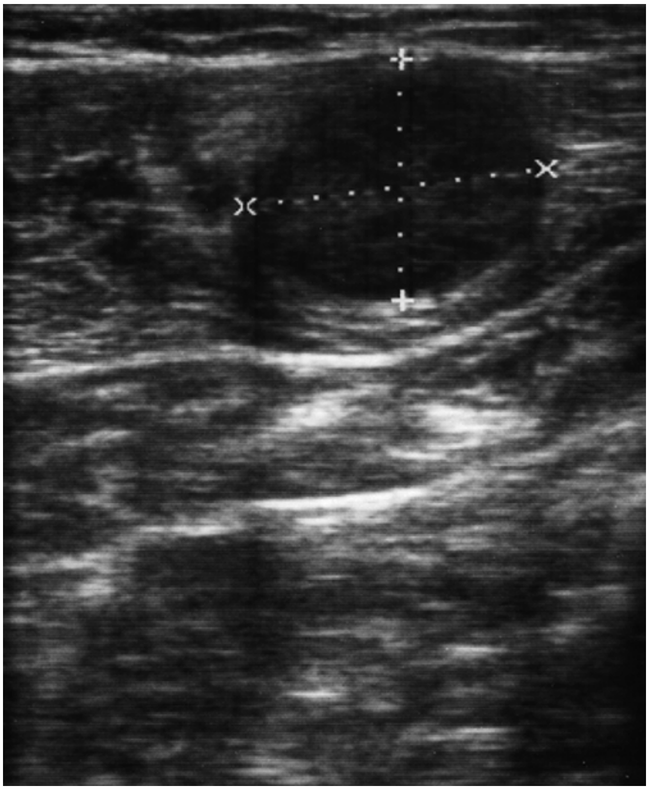

**Fig. 6.17** Palpable mass in the abdominal wall following laparotomy for endometriosis. The axis of the tumor (+, ×)

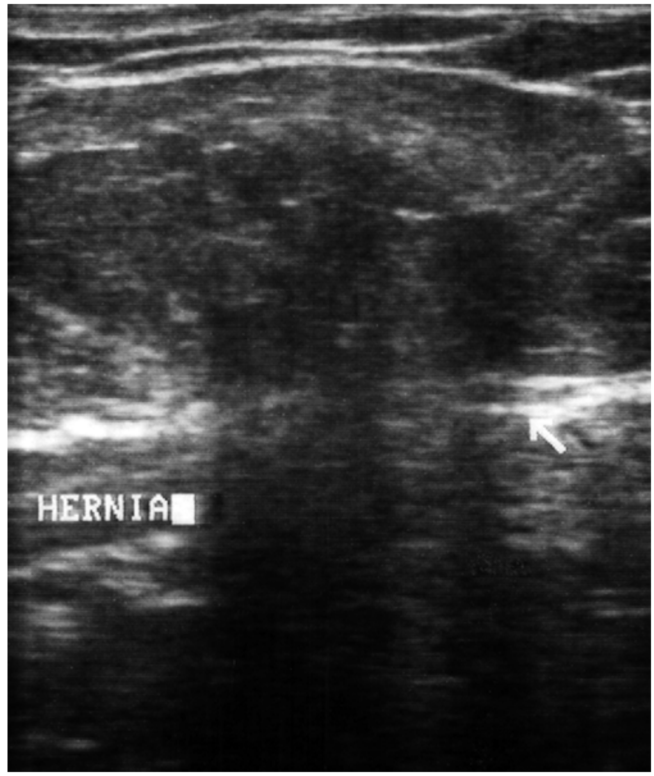


**Fig. 6.18** Ventral hernia. Notice the hyperechoic fascia on both sides of the hernia sac. Points to fascia edge (*arrow*)

appears as a hypoechoic solid lesion, with scattered internal echoes and internal vascularity that can be demonstrated with color Doppler [21] (Fig. 6.17).

### Abdominal Wall Hernias

In general, a hernia occurs when there is a protrusion of an organ or tissue through a defect in the surrounding fascia. Anterior abdominal wall hernias can be classified as either ventral hernias or groin hernias. Ultrasound can aid to diagnose a hernia, to define its contents, and to identify other possible defects. The hernia contents could be reducible, incarcerated, or strangulated. A strangulated hernia entails vascular compromise to the contents of the hernia sac that are irreducible through a small defect.

### Ventral Hernias

Ventral hernias can be classified as umbilical, epigastric, or Spigelian hernias. In the event of acute incarceration, patients may present with strangulation or intestinal obstruction. Imaging, including ultrasonography and CT scan, may also play a role in diagnosis, particularly in evaluating the contents of the hernia sac and the size of the fascial defect. When bowel is contained with the hernia sac, US will demonstrate distinctive bright echoes from the intestinal gas [10]. Ultrasonography is also an especially useful and expedient way to screen for abdominal wall hernias, when there is no palpable mass or when there is a palpable mass of questionable etiology particularly in cases where there is pain and swelling in postoperative patients (Fig. 6.18).

Umbilical and epigastric hernias represent 10 % of all abdominal wall hernias [16]. Epigastric hernias can be found in 3–5 % of adults and are more common in men [16]. These hernias are located along the linea alba between the xiphoid process and the umbilicus, usually within 5–6 cm of the umbilicus. They are more common in patients with a single aponeurotic decussation at the linea alba as opposed to the usual decussation of fibers from all three muscle aponeuroses. There may be multiple defects, and most are off the midline. The fascial defect is usually small in size, and often pain is present due to incarceration of preperitoneal fat. Due to their association with pain and small size, operative repair is usually recommended. Ultrasound imaging of the abdominal wall can help to establish the diagnosis by identifying the mass, defining the fascial defect, and diagnosing possible multiplicity (Fig. 6.19).

Spigelian hernias are located along the Spigelian fascia, which is the aponeurotic layer between the rectus muscles medially and the semilunar line laterally (Figs. 6.3 and 6.20). They predominantly occur at the level of or below the arcuate line. Because the posterior rectus sheath comprises only

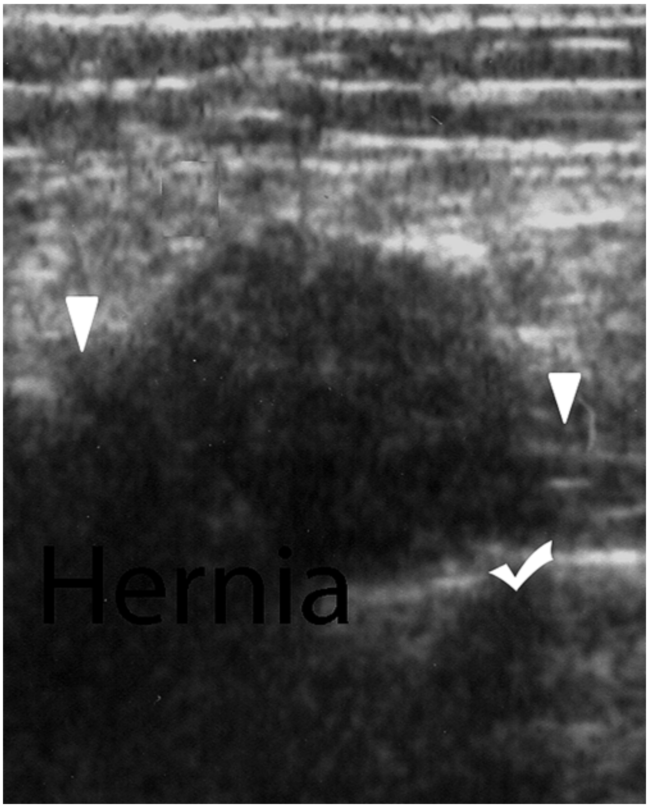


**Fig. 6.19** Epigastric hernia. Notice the defect (→) in the aponeurosis (✓)

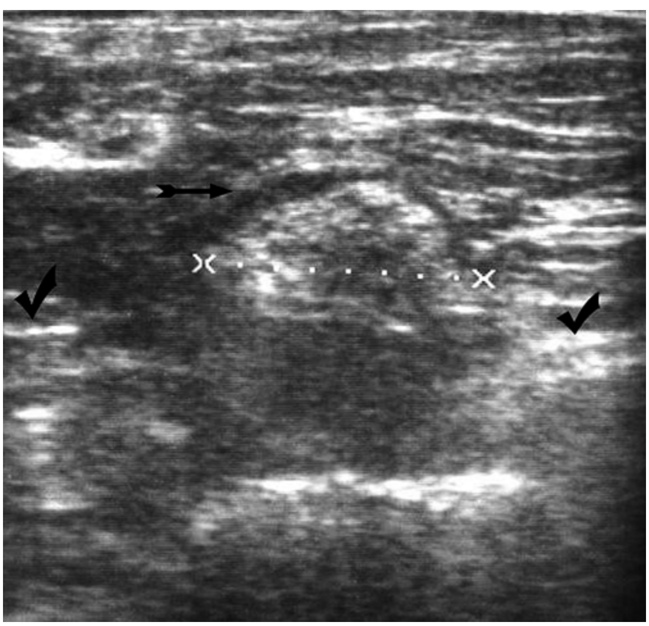

**Fig. 6.20** Spigelian hernia. Note the defect in the aponeurosis (✓) and the hernia sac (→) containing small intestine (*dotted line*)

the transversalis fascia here, it is naturally weaker and more prone to herniation. The hernias are often intraparietal in that the hernia sac does not penetrate the external oblique

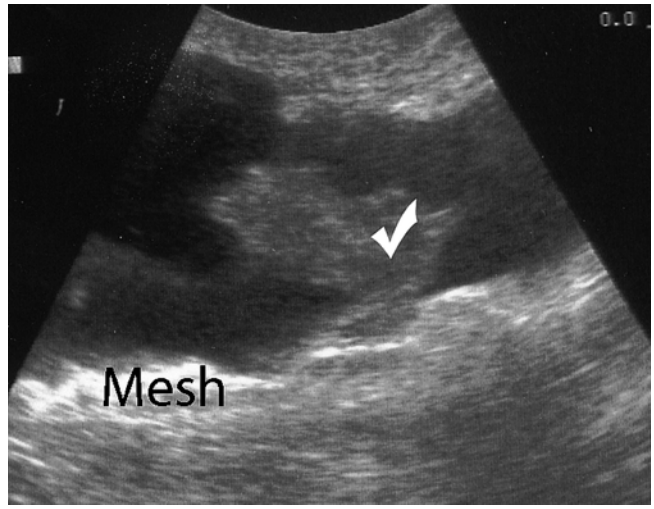


**Fig. 6.21** Postoperative seroma following ventral hernia repair. Notice the mesh and the seroma with residual hematoma (✓)

aponeurosis. Because of their posterior location to the intact external oblique, a bulge is often not apparent on physical examination. An ultrasound of the abdominal wall often demonstrates a defect along the linea semilunaris, regardless of the presence of herniated bowel [22]. When evaluating with sonography, the transducer probe should be placed transversely at the lateral border of the rectus muscle (linea semilunaris) at the level of the umbilicus and should be shifted inferiorly in scanning for a Spigelian hernia [23].

Incisional hernias occur when intra-abdominal contents herniate through previous fascial incisions, the integrity of which may have been compromised by excessive tension, inadequate healing due to various conditions, conditions associated with increased intra-abdominal pressure, or surgical site infections. Following repair of large incisional hernias, usually with mesh, the incidence of seroma or hematoma within the cavity is rather high. In the postoperative period, questions concerning the nature of these masses frequently occur. US can define these collections, and if infection is present, drainage should be performed (Fig. 6.21). US-guided aspiration of these fluid collections is safer than blind aspiration. Presence of infected fluid permits immediate placement of drain.

## Inguinal Region Anatomy

The inguinal region is a continuation of the abdominal wall muscles and fascia, yet it is an anatomically distinct region that warrants a separate discussion that is reviewed below.

At the inguinal region, the external oblique aponeurosis serves as the anterior, superficial border of the inguinal canal (Fig. 6.22). The inguinal ligament (Poupart's ligament) is actually the inferior edge of the external oblique aponeurosis

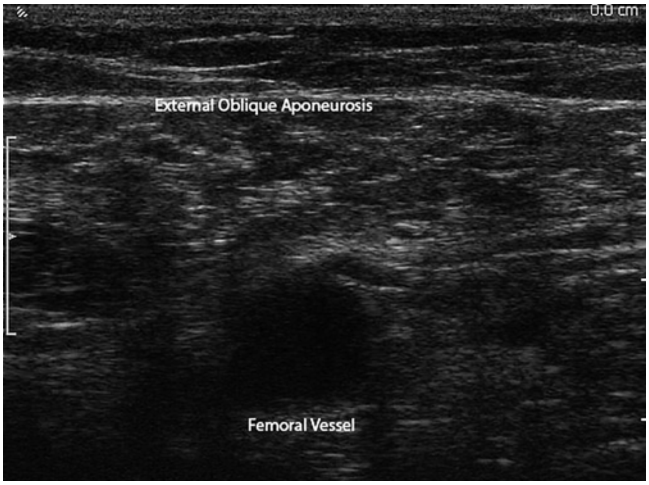


**Fig. 6.22** Normal anatomy of the inguinal region (female)

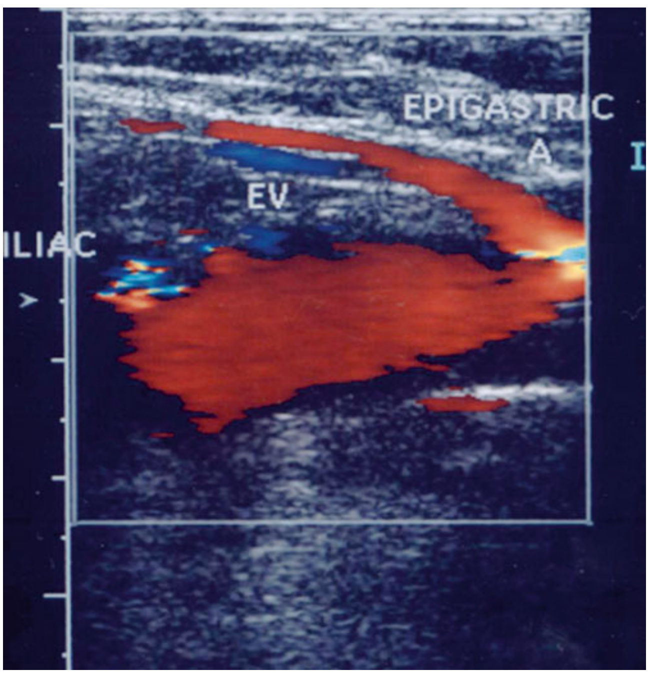


**Fig. 6.23** Vasculature of groin with ultrasound using color Doppler

and runs from the anterior superior iliac spine to the pubic tubercle. The superior border of the canal is marked by the internal oblique muscle. As the internal oblique muscle and its aponeurosis courses medially towards the pubic tubercle, it joins the transversalis aponeurosis to form the conjoined tendon (which is actually present in only 5–10 % of patients) [16]. The floor of the inguinal canal is formed by the transversalis fascia and the margins of the inguinal floor are referred to as Hesselbach's triangle. The superolateral border of the triangle is marked by the inferior epigastric vessels (Fig. 6.23). The medial border is marked by the rectus sheath, and the inferior border is marked by the inguinal ligament.

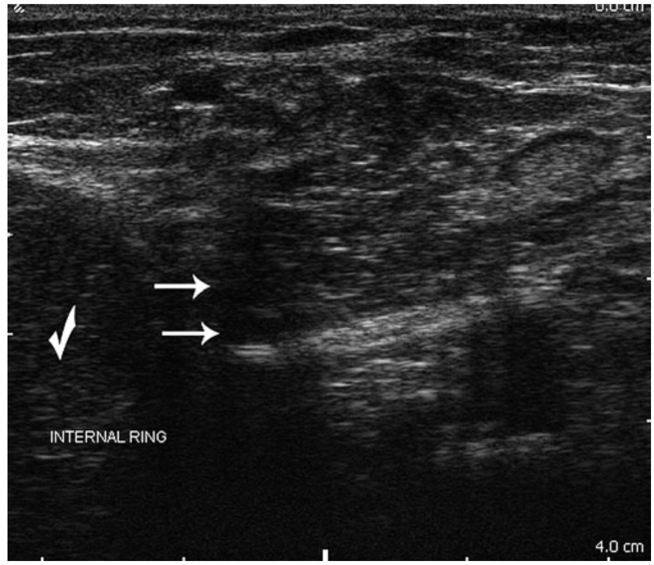


**Fig. 6.24** Ultrasound of the inguinal region in a male without a demonstrable hernia. *Arrows* point to the epigastric vessels; *checkmark* indentifies internal ring

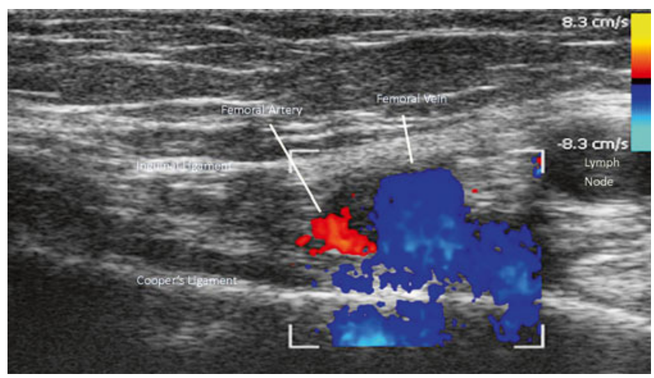


**Fig. 6.25** Femoral canal anatomy on ultrasound with color Doppler. A femoral hernia occurs medial to the femoral vein

The inguinal canal, which is about 4 cm in length, extends between the deep and superficial inguinal rings. The deep inguinal ring is an opening in the transversalis fascia through which the spermatic cord or round ligament pass prior to entering the inguinal canal. On ultrasonography, the cord can be seen in longitudinal and transverse planes as a heterogeneous echogenic structure with associated hypoechoic tubules and vessels, originating at the internal inguinal ring [23] (Fig. 6.24).

The femoral canal lies inferior to the inguinal ligament (Fig. 6.25). It is considered an anatomically distinct region from the inguinal canal. The iliopubic tract and Cooper's ligament constitute its anterior and posterior borders, respectively. The femoral vein lies laterally and medially; the pubic tubercle forms the apex of the femoral canal triangle [24].

## Inguinal Region Pathology and Intervention

The etiology of groin masses may be difficult to diagnose based on clinical examination alone, especially in the obese and difficult-to-examine patients. Ultrasonography has proven to be a valuable tool in differentiating between the pathologies that may be encountered in the groin region. It is indicated in the preoperative setting as a tool to diagnose hernias as well as in the postoperative period when swelling of that region could be interpreted as a recurrent hernia, seroma, or hematoma. Seromas are frequently associated with laparoscopic repair of inguinal hernias.

### Groin Masses

Superficial masses that appear as hypoechoic fluid collections in the groin region on sonography may be a cyst, hematoma, seroma, or abscess. In a patient who has had recent surgery in the groin region, a hematoma or seroma should be suspected (Fig. 6.26). An abscess may appear as a more complex fluid collection with septations and debris on sonography. Ultrasound-guided aspiration of the fluid collection can further aid in diagnosis if warranted.

**Fig. 6.26** Postoperative hematoma. Spermatic cord hematoma following inguinal hernia repair. *Arrow* points to epigastric vessel

A solid mass in the groin region may be a lymph node, an aneurysm, or a neoplasm (Fig. 6.27). On US, the pathologic lymph nodes may have varying echogenicities, can appear as multilobulated, and have varying amount of fat at the hilum [7]. Additionally, on ultrasound, nodes that are suspicious or metastatic may be spherical in shape (versus ellipsoid) and have a thickness-to-length ratio greater than 2:3 and a diameter greater than 5 mm [25]. The adenopathy may easily be confused with an abscess [7], and clinical correlation and ultrasound-guided aspiration or core biopsy may be warranted. Metastatic lymph nodes are most common from tumors arising from the genitourinary tract (vulva or vagina in females, penis or testes in males), the distal gastrointestinal tract (distal rectum and anus), or from the lower extremities. In general they are devoid of fat at the hilum. Ultrasonography is particularly useful in the surveillance of inguinal lymphatic and nodal basins in high-risk melanoma patients [26, 27] (Fig. 6.28).

Additional masses that can be encountered in the groin region are undescended and retractile testes (Fig. 6.29). The testes will appear as a homogeneous, predominantly hypoechoic mass with smooth borders and fine granularity on ultrasound [10]. Groin masses should be differentiated from scrotal masses for which there is an additional differential that includes hydroceles, varicocele, epididymitis or epididymal cyst, or testicular masses. Hydroceles are not continuous with the peritoneal cavity, and this can be confirmed with ultrasound. Varicoceles will demonstrate venous flow on Doppler ultrasound that is accentuated with the Valsalva maneuver [24]. There is a differentiation between the applicability of power Doppler and spectral (pulsed wave) color Doppler, which is especially important in the groin and scrotal region. Power Doppler allows for detection and direction of blood flow but is prone to motion artifact [28]. Spectral Doppler allows for the identification of artery versus venous flow and both must be identified in evaluating blood flow to the testes. Sonographic findings of

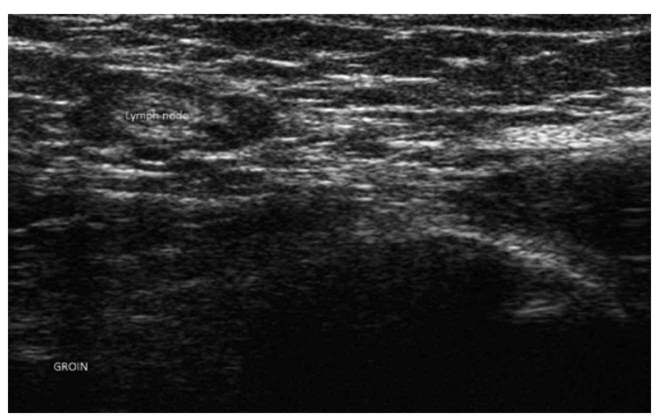


**Fig. 6.27** Normal inguinal adenopathy. Notice the presence of increased echogenicity at the hilum indicating fat

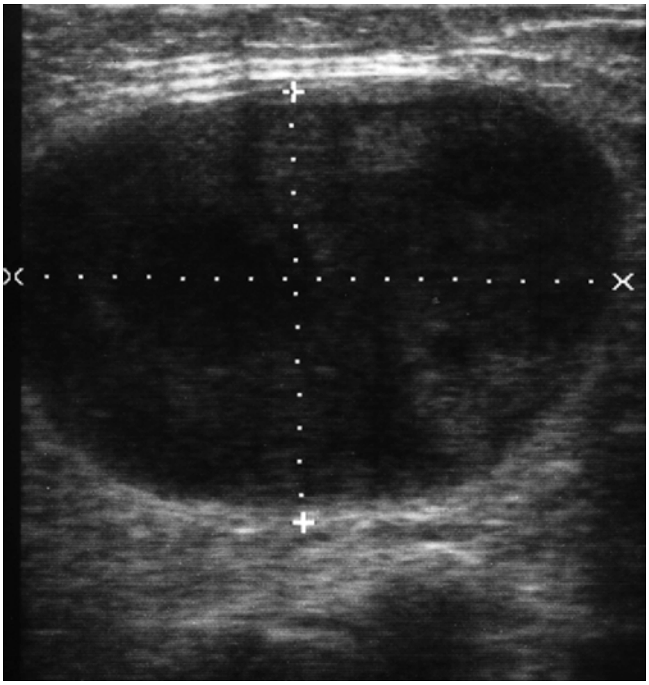

**Fig. 6.28** A pathological lymph node may have irregular borders, is heterogeneous, and lacks hilar fat and thus appears hypoechoic. Fine-needle aspiration of the node showed melanoma

**Table 6.4** Ultrasonographic appearance of groin masses

| Inguinal region | Sonographic features |
|---|---|
| Undescended/retractile testes | Homogeneous |
| | Predominantly hypoechoic mass with smooth borders and fine granularity |
| Lymphadenopathy | Varying echogenicities |
| | May be multilobulated |
| | Metastatic nodes may be spherical in shape (versus ellipsoid), with diameter greater than 5 mm |
| Neoplasm | Solid |
| | Well defined, mobile, hypoechoic if benign |
| | Variable echogenicity, fixed, irregular if malignant |
| *Scrotal masses* | |
| Varicocele | Venous flow on Doppler ultrasound that is accentuated with the Valsalva maneuver |
| Epididymitis | Enlargement of the epididymis |
| | Decreased echogenicity due to edema |
| | Increased blood flow on Doppler ultrasound compared to the unaffected side |
| Hydrocele | Anechoic |
| | Does not communicate with peritoneal cavity |
| Testicular mass | Solid |
| | May be irregular |

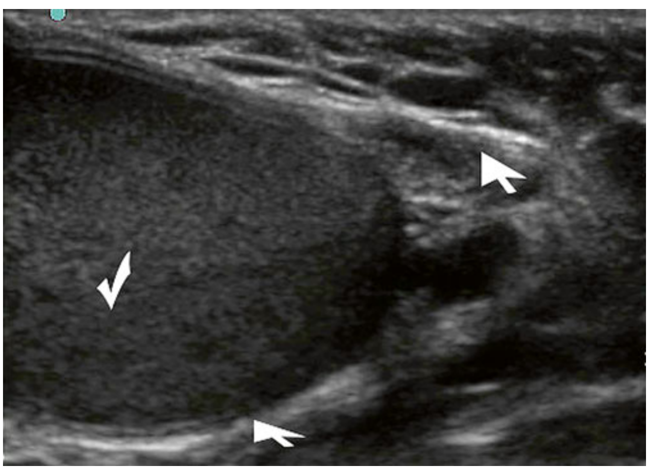

**Fig. 6.29** Indirect inguinal hernia. Notice the location of the testicle (✓) within the inguinal canal. *Arrows* point to hernia sac

epididymitis include enlargement of the epididymis, decreased echogenicity due to edema, and increased blood blow on Doppler ultrasound compared to the unaffected side [28].

If the mass is in the femoral region, a femoral artery aneurysm or pseudoaneurysm should be suspected. Such a mass may be pulsatile and can easily be characterized as turbulent flow on sonography with color Doppler capabilities [24]. This flow of pseudoaneurysm is described as typical yin-yang flow on Doppler examination [29]. Ultrasound-guided injection of thrombin into pseudoaneurysm cavities has become more of common practice since its initial success was reported in 1997 [30] (Table 6.4).

## Groin Hernias

The most common mass encountered in the groin region is a hernia. A groin hernia is either an inguinal hernia or a femoral hernia.

## Inguinal Hernia

Inguinal hernias comprise up to 75 % of abdominal wall hernias [16]. Men are more likely, up to 25 times more, to have an inguinal hernia than woman. These hernias can be classified as either direct or indirect hernias. A direct inguinal hernia is marked by a defect in the floor of the inguinal canal, whereby the hernia sac protrudes medially to the deep inguinal ring inferior epigastric vessels. An indirect inguinal hernia is defined as a hernia sac and its contents passing though the deep inguinal ring, laterally to the inferior epigastric vessels, and alongside (usually medially) the spermatic cord or

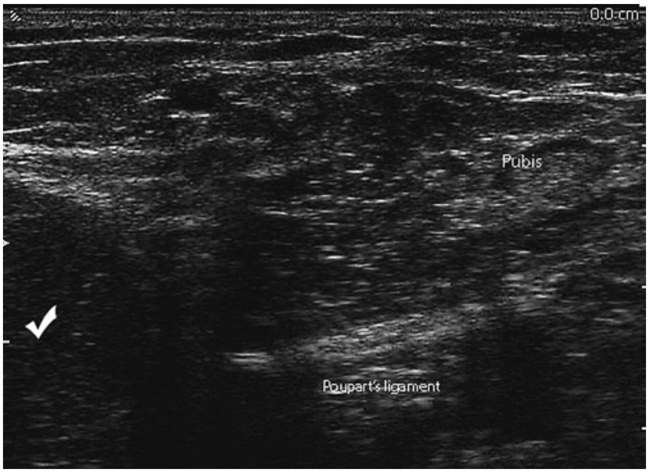


**Fig. 6.30** Ultrasound of the inguinal region in a patient with a right indirect inguinal hernia (✓)

round ligament (Fig. 6.30). US is useful in diagnosing small indirect inguinal hernias in the patient presenting with acute onset of groin pain due to small incarcerated hernia containing preperitoneal fat.

An ultrasound, with its high degree of sensitivity and specificity in detection, can also aid in the diagnosis, particularly with occult hernias [31, 32]. Ultrasound has been shown to be quite accurate in identifying the presence of an inguinal hernia (>90 % accuracy) [32]. It can also be used to aid in identifying the type of hernia present (e.g., direct versus indirect) and in evaluating the viability of bowel that may be incarcerated [33, 34]. In identifying an indirect hernia on sonography, the transducer probe is positioned longitudinally (parallel to the inguinal canal), and the indirect hernia will be seen protruding anteriorly towards the transducer, lateral to the inferior epigastric vessel, at its origin, and then coursing medially along the canal towards the pubic tubercle and superficial ring [23]. In identifying a direct inguinal hernia, the transducer is again placed longitudinally along the inguinal canal and moved medially to identify a sac that protrudes anteriorly, originating medial to the inferior epigastric artery [23] (Figs. 6.30 and 6.31). The hernia sac's anterior protrusion can be accentuated with the Valsalva maneuver. The presence of peristalsis suggests the presence of viable bowel in the hernia sac [35]. Computed tomography (CT) of the abdomen/pelvis will also demonstrate an inguinal hernia.

Complications of an inguinal hernia repair include urinary retention, orchitis, groin pain from nerve injury, scrotal edema, seromas, hematomas, and abscesses. Postoperative fluid collections can be characterized with the use of ultrasonography. Seromas that are concerning for possible infection may be aspirated using ultrasound guidance. In cases of scrotal edema and hematomas following inguinal hernia repair, ultrasonography with Doppler can be utilized to ensure that vascular flow to the testes is not compromised (Fig. 6.26).

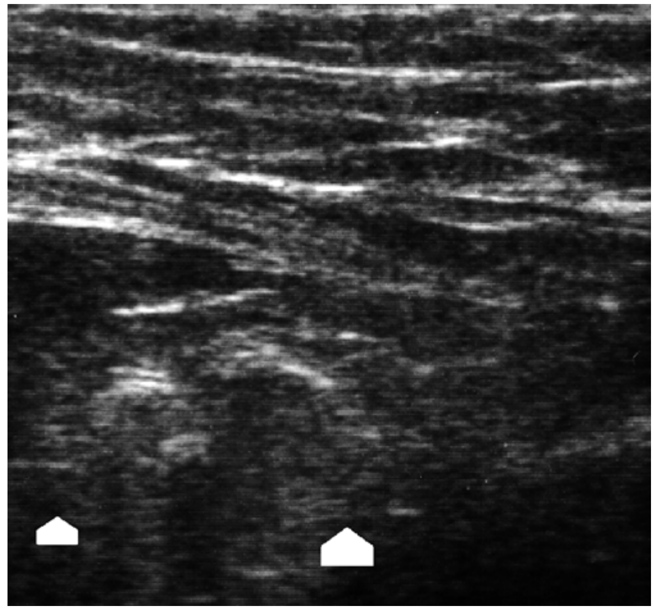

**Fig. 6.31** Direct inguinal hernia. *Arrows* point to the defect in transversalis fascia

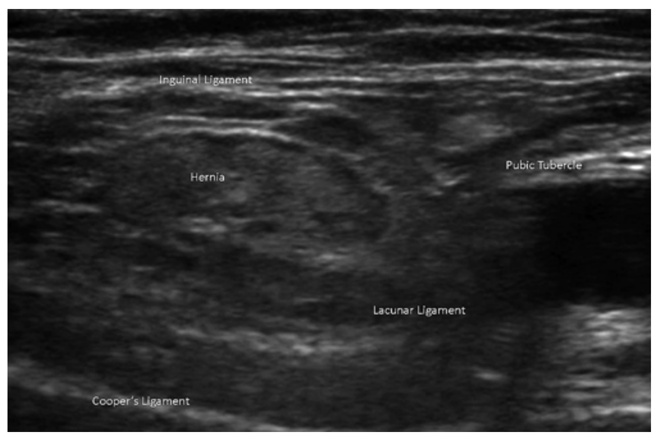


**Fig. 6.32** Femoral hernia

## Femoral Hernias

Femoral hernias are more likely to occur in women than men and are also associated with a higher risk of strangulation than inguinal hernias. In patients presenting with small bowel obstruction of uncertain origin, an ultrasound could be invaluable in the diagnosis of occult femoral hernias (Fig. 6.32). The transducer is placed inferior to the inguinal ligament and the femoral vein identified so that the area medial to it can be

**Table 6.5** Ultrasound features of hernias

| | |
|---|---|
| Abdominal wall hernias | May be reducible with transducer compression<br>Distinctive bright echoes from the intestinal gas and presence of peristalsis if bowel presents with hernia sac |
| Groin hernia | May be reducible with transducer compression<br>Distinctive bright echoes from the intestinal gas and presence of peristalsis if bowel present within hernia sac |
| Inguinal hernia | Indirect hernia: arises lateral to epigastric vessel (can be viewed with Doppler)<br>Direct hernia: arises medial to epigastric vessel (can be viewed with Doppler) |
| Femoral hernia | Posterior to inguinal ligament and medial to femoral vessels |
| Femoral pseudoaneurysm | Turbulent flow, "yin-yang" flow on sonography with color Doppler |

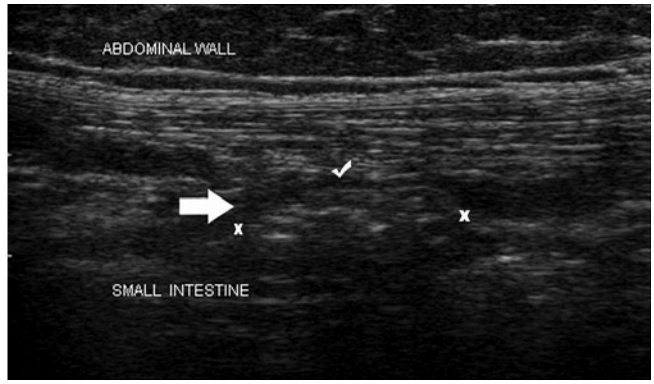


**Fig. 6.33** Ultrasound-guided mapping of small bowel adhesions to abdominal wall. *Arrow* points to small intestine (*X*) adhesed to abdominal wall (✓)

scanned for the presence of a hernia [23]. It is important to note that if the patient is asked to do the Valsalva maneuver during the exam, the femoral vein will dilate with the maneuver and could be mistaken for a hernia [23] (Table 6.5).

## Interventional Ultrasound of the Abdominal Wall in the Perioperative Setting

### Mapping of Abdominal Wall Adhesions

First described by Sigel et al., in 1991, the technique of graded compression, using ultrasound to detect and map abdominal wall adhesions prior to surgery has been utilized to identify safe access to the abdominal cavity [36, 37]. During real-time imaging, the abdominal viscera will demonstrate movement that varies with respiration. This movement, called visceral slide, can also be induced with manual graded compression with an ultrasound transducer. When this visceral slide appears restricted on manual compression, visceral adhesions to the abdominal wall are suspected in that particular region (Fig. 6.33). In this manner, one can map out the location of adhesions and thus avoid these areas when placing trocars during laparoscopic surgery. This technique has been shown to be reliable in preventing trocar-induced visceral injuries and its use is advocated in highly selective cases in planning abdominal wall cannulation for laparoscopy in patients with prior scars [38].

### Perioperative Nerve Block

Abdominal wall nerve blocks have an established role in providing perioperative analgesia, and the majority of these blocks are now being performed with ultrasound guidance. Even though the majority of these nerve blocks are performed by anesthesiologists, the surgeon should be knowledgeable of the type of nerve blocks available in the perioperative setting to better select type of anesthesia given to the patient [39].

The nerve supply to the abdominal wall arises from the anterior rami of the lower thoracic nerves and the first lumbar nerve. The seventh through twelfth thoracic nerves course anteromedially in the transversus abdominis plane anterior to the transversalis fascia and provide sensory and motor branches to the abdominal wall. The groin region includes several important nerves: iliohypogastric nerve, the ilioinguinal nerve, and the genital branch of the genitofemoral nerve. The iliohypogastric and ilioinguinal nerves are located medial and superior the anterior superior iliac spine beneath the external oblique aponeurosis, where they penetrate the internal oblique muscles and provide sensation to the skin, base of the penis, and upper medial thigh. The iliohypogastric nerve runs along the anterior surface of the internal oblique aponeurosis, medial and superior to the deep inguinal ring. The ilioinguinal nerve runs anterior to the spermatic cord in the inguinal canal. The genital branch of the genitofemoral nerve runs alongside the spermatic cord or round ligament in the inguinal canal and provides sensation to the cremasteric muscle and scrotal or labial skin.

The three most established ultrasound-guided nerve blocks of the abdominal wall are the ilioinguinal/hypogastric, transversus abdominis plane, and rectus sheath blocks (Table 6.6).

The ilioinguinal/hypogastric nerve block entails the infusion of local anesthetic typically 1–2 cm superior and medial to the anterior superior iliac spine. The use of ultrasound enhances the accuracy and efficacy of the block (Fig. 6.3). On ultrasound the nerve lies in the fascial layer between the internal oblique and the transversus abdominis muscles and appears as a hypoechoic structure surrounded by the more echogenic muscles and fat [40]. Since it is in close proximity to the deep circumflex artery, the use of color Doppler to

**Table 6.6** Ultrasound-guided nerve blocks

| Type of block | Location of anesthetic injection |
|---|---|
| Ilioinguinal/ iliohypogastric block | Within 2 cm to anterior superior iliac spine |
| | Inject below the external oblique muscle and internal oblique fascia |
| | Nerve appears as a hypoechoic structure surrounded by the more echogenic muscles and fat |
| | Ilioinguinal nerve lies in the same plane as the deep circumflex artery (can be seen with Doppler) |
| Transversus abdominis plane block | Inject below the internal oblique fascia within the transversus muscle, anterior to the transversalis fascia |
| | Location of administration most commonly within triangle of Petit or along midaxillary line |
| Rectus sheath block | Inject along the lateral margin of the plane between the rectus muscles and posterior sheath, where intercostal nerves enter the sheath |

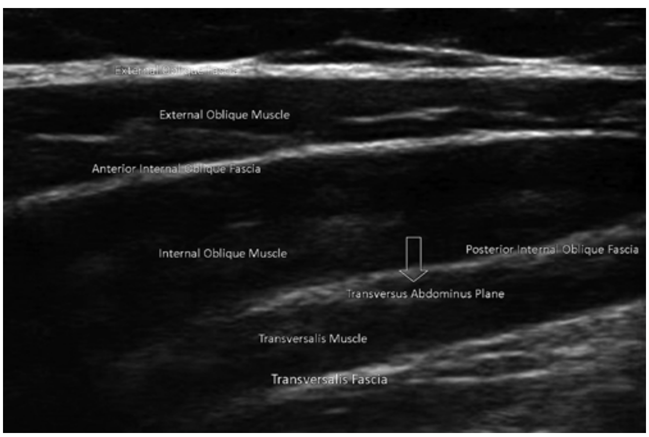


**Fig. 6.34** Transversus abdominis plane block. Regional block for hernia repair is facilitated by infiltrating this space (*arrow*) with local anesthetic

identify this artery helps to identify the nerve [40]. The hypogastric nerve can be found medial to the ilioinguinal nerve. This ilioinguinal/hypogastric nerve block is routinely used for perioperative anesthesia during inguinal herniorrhaphies [41]. The nerve block can also be used in the postoperative setting to treat chronic pain following groin surgery [42], although its utility and long-term success have been questioned [43].

The transversus abdominis plane (TAP) block involves the ultrasound-guided infusion of the local anesthetic deep to the fascial layer (Fig. 6.34). They can be used for both laparoscopic and open procedures. There is no one method or protocol that has been demonstrated to be superior [44], but it is clear that the block in combination of local anesthesia offers better postoperative pain control than conventional local anesthesia alone [44, 45]. Long-term infusion of analgesics for chronic somatic pain via an indwelling catheter in the transversus abdominis plane has also been described [46].

**Conclusion**

Ultrasonography has a valuable role in the diagnosis and management of abdominal wall and groin pathology. The surgeon who is familiar with the anatomy and the wide differential of pathology that is reviewed in this chapter is especially equipped to utilize this modality for both diagnostic and therapeutic purposes in both the ambulatory and perioperative settings.

## References

1. Velasco JM, Hieken TJ. Other transabdominal ultrasound. In: Machi J, Staren ED, editors. Ultrasound for surgeons. 2nd ed. Philadelphia: Lippincott Williams & Wilkins; 2005.
2. BERLYNE GM. Ultrasonics in renal biopsy: an aid to determination of kidney position. Lancet. 1961;2(7205):750–1. PubMed PMID: 13867961. eng.
3. Hancke S, Holm HH, Koch F. Ultrasonically guided percutaneous fine needle biopsy of the pancreas. Surg Gynecol Obstet. 1975;140(3):361–4. PubMed PMID: 1114427. eng.
4. Staren ED, Torp-Pedersen S. General interventional ultrasound. In: ED S, editor. Ultrasound for the surgeon. Philadelphia: Lippincott-Raven Publishers; 1997. p. 137–60.
5. Nolsoe C, Nielsen L, Torp-Pedersen S, Holm HH. Major complications and deaths due to interventional ultrasonography: a review of 8000 cases. J Clin Ultrasound. 1990;18(3):179–84. PubMed PMID: 2155937. eng.
6. Deitch EA, Engel JM. Ultrasonic diagnosis of surgical diseases of the anterior abdominal wall. Surg Gynecol Obstet. 1980;151(4):484–6. PubMed PMID: 6447925. eng.
7. Lineaweaver W, Vlasak M, Muyshondt E. Ultrasonic examination of abdominal wall and groin masses. South Med J. 1983;76(5):590–2. PubMed PMID: 6221409. eng.
8. Mendes DA, Nahas FX, Veiga DF, Mendes FV, Figueiras RG, Gomes HC, et al. Ultrasonography for measuring rectus abdominis muscles diastasis. Acta Cir Bras. 2007;22(3):182–6. PubMed PMID: 17546290. eng.
9. Fukuda T, Sakamoto I, Kohzaki S, Uetani M, Mori M, Fujimoto T, et al. Spontaneous rectus sheath hematomas: clinical and radiological features. Abdom Imaging. 1996;21(1):58–61. PubMed PMID: 8672974. eng.
10. Jain N, Goyal N, Mukherjee K, Kamath S. Ultrasound of the abdominal wall: what lies beneath? Clin Radiol. 2013;68:85–93. PubMed PMID: 22854266. ENG.
11. Lewiss RE, Wu S. Ultrasound diagnosis of rectus sheath hematoma. J Emerg Med. 2012;43(5):e337–8. PubMed PMID: 21820260. eng.
12. Klingler PJ, Wetscher G, Glaser K, Tschmelitsch J, Schmid T, Hinder RA. The use of ultrasound to differentiate rectus sheath hematoma from other acute abdominal disorders. Surg Endosc. 1999;13(11):1129–34. PubMed PMID: 10556453. eng.
13. Berná-Serna JD, Sánchez-Garre J, Madrigal M, Zuazu I, Berná-Mestre JD. Ultrasound therapy in rectus sheath hematoma. Phys Ther. 2005;85(4):352–7. PubMed PMID: 15794705. eng.

14. Yeh HC, Rabinowitz JG. Ultrasonography and computed tomography of inflammatory abdominal wall lesions. Radiology. 1982; 144(4):859–63. PubMed PMID: 6213981. eng.
15. Gokhale S. Sonography in identification of abdominal wall lesions presenting as palpable masses. J Ultrasound Med. 2006;25(9): 1199–209. PubMed PMID: 16929022. eng.
16. Turanage RH, Richardson KA, Benjamin DL, McDonald JC. Abdominal wall, umbilicus, peritoneum, mesenteries, omentum, and retroperitoneum. In: Townsend CM, Daniel Beauchamp R, Mark Evers B, Mattox KL, editors. Sabiston textbook of surgery. 18th ed. Philadelphia: Saunders/Elsevier; 2008.
17. Kishi K, Takifuji K, Shirai S, Sonomura T, Sato M, Yamaue H. Brachytherapy technique for abdominal wall metastases of colorectal cancer: ultrasound-guided insertion of applicator needle and a skin preservation method. Acta Radiol. 2006;47(2):157–61. PubMed PMID: 16604961. eng.
18. Lee RK, Cho CC, Tong CS, Ng AW, Liu EK, Griffith JF. Ultrasound of the abdominal wall and groin. Can Assoc Radiol J. 2013;64: 295–305. PubMed PMID: 23103240. ENG.
19. Höroldt BS, Lee FK, Gleeson D, McAlindon ME, Sanders DS. Ultrasound guidance in the placement of a percutaneous endoscopic gastrostomy (PEG): an adjuvant technique in patients with abdominal wall varices? Dig Liver Dis. 2005;37(9):709–12. PubMed PMID: 15925555. eng.
20. Gidwaney R, Badler RL, Yam BL, Hines JJ, Alexeeva V, Donovan V, et al. Endometriosis of abdominal and pelvic wall scars: multimodality imaging findings, pathologic correlation, and radiologic mimics. Radiographics. 2012;32(7):2031–43. PubMed PMID: 23150856. eng.
21. Hensen JH, Van Breda Vriesman AC, Puylaert JB. Abdominal wall endometriosis: clinical presentation and imaging features with emphasis on sonography. AJR Am J Roentgenol. 2006;186(3):616–20. PubMed PMID: 16498086. eng.
22. Deitch EA, Engel JM. Spigelian hernia: an ultrasonic diagnosis. Arch Surg. 1980;115(1):93. PubMed PMID: 7350893. eng.
23. Jamadar DA, Jacobson JA, Morag Y, Girish G, Ebrahim F, Gest T, et al. Sonography of inguinal region hernias. AJR Am J Roentgenol. 2006;187(1):185–90. PubMed PMID: 16794175. eng.
24. Shadbolt CL, Heinze SB, Dietrich RB. Imaging of groin masses: inguinal anatomy and pathologic conditions revisited. Radiographics. 2001;21 Spec No:S261–71. PubMed PMID: 11598262. eng.
25. Uren RF, Howman-Giles R, Thompson JF, Shaw HM, Roberts JM, Bernard E, et al. High-resolution ultrasound to diagnose melanoma metastases in patients with clinically palpable lymph nodes. Australas Radiol. 1999;43(2):148–52. PubMed PMID: 10901892. eng.
26. Voit C, Schoengen A, Schwürzer-Voit M, Weber L, Ulrich J, Sterry W, et al. The role of ultrasound in detection and management of regional disease in melanoma patients. Semin Oncol. 2002;29(4): 353–60. PubMed PMID: 12170438. eng.
27. Hofmann U, Szedlak M, Rittgen W, Jung EG, Schadendorf D. Primary staging and follow-up in melanoma patients–monocenter evaluation of methods, costs and patient survival. Br J Cancer. 2002;87(2):151–7. PubMed PMID: 12107834. Pubmed Central PMCID: PMC2376106. eng.
28. Blaivas M, Brannam L. Testicular ultrasound. Emerg Med Clin North Am. 2004;22(3):723–48, ix. PubMed PMID: 15301848. eng.
29. Mitchell DG, Needleman L, Bezzi M, Goldberg BB, Kurtz AB, Pennell RG, et al. Femoral artery pseudoaneurysm: diagnosis with conventional duplex and color Doppler US. Radiology. 1987; 165(3):687–90. PubMed PMID: 3317501. eng.
30. Liau CS, Ho FM, Chen MF, Lee YT. Treatment of iatrogenic femoral artery pseudoaneurysm with percutaneous thrombin injection. J Vasc Surg. 1997;26(1):18–23. PubMed PMID: 9240316. eng.
31. Robinson A, Light D, Kasim A, Nice C. A systematic review and meta-analysis of the role of radiology in the diagnosis of occult inguinal hernia. Surg Endosc. 2013;27:11–8. PubMed PMID: 22733195. ENG.
32. Light D, Ratnasingham K, Banerjee A, Cadwallader R, Uzzaman MM, Gopinath B. The role of ultrasound scan in the diagnosis of occult inguinal hernias. Int J Surg. 2011;9(2):169–72. PubMed PMID: 21059415. eng.
33. Zhang GQ, Sugiyama M, Hagi H, Urata T, Shimamori N, Atomi Y. Groin hernias in adults: value of color Doppler sonography in their classification. J Clin Ultrasound. 2001;29(8):429–34. PubMed PMID: 11745848. eng.
34. Babkova IV, Bozhko VV. Ultrasound assessment in diagnosis of uncomplicated inguinal hernia. Khirurgiia (Mosk). 1999;(2):46–50. PubMed PMID: 10081255. rus
35. Jamadar DA, Jacobson JA, Morag Y, Girish G, Dong Q, Al-Hawary M, et al. Characteristic locations of inguinal region and anterior abdominal wall hernias: sonographic appearances and identification of clinical pitfalls. AJR Am J Roentgenol. 2007;188(5):1356–64. PubMed PMID: 17449782. eng.
36. Sigel B, Golub RM, Loiacono LA, Parsons RE, Kodama I, Machi J, et al. Technique of ultrasonic detection and mapping of abdominal wall adhesions. Surg Endosc. 1991;5(4):161–5. PubMed PMID: 1839571. eng.
37. Kodama I, Loiacono LA, Sigel B, Machi J, Golub RM, Parsons RE, et al. Ultrasonic detection of viscera slide as an indicator of abdominal wall adhesions. J Clin Ultrasound. 1992;20(6):375–80. PubMed PMID: 1328308. eng.
38. Caprini JA, Arcelus JA, Swanson J, Coats R, Hoffman K, Brosnan JJ, et al. The ultrasonic localization of abdominal wall adhesions. Surg Endosc. 1995;9(3):283–5. PubMed PMID: 7597599. eng.
39. Herring AA, Stone MB, Nagdev AD. Ultrasound-guided abdominal wall nerve blocks in the ED. Am J Emerg Med. 2012;30(5):759–64. PubMed PMID: 21570238. eng.
40. Gofeld M, Christakis M. Sonographically guided ilioinguinal nerve block. J Ultrasound Med. 2006;25(12):1571–5. PubMed PMID: 17121952. eng.
41. Bærentzen F, Maschmann C, Jensen K, Belhage B, Hensler M, Børglum J. Ultrasound-guided nerve block for inguinal hernia repair: a randomized, controlled, double-blind study. Reg Anesth Pain Med. 2012;37(5):502–7. PubMed PMID: 22705951. eng.
42. Thomassen I, van Suijlekom JA, van de Gaag A, Ponten JE, Nienhuijs SW. Ultrasound-guided ilioinguinal/iliohypogastric nerve blocks for chronic pain after inguinal hernia repair. Hernia. 2013;17:329–32. PubMed PMID: 23015156. ENG.
43. Bischoff JM, Koscielniak-Nielsen ZJ, Kehlet H, Werner MU. Ultrasound-guided ilioinguinal/iliohypogastric nerve blocks for persistent inguinal postherniorrhaphy pain: a randomized, double-blind, placebo-controlled, crossover trial. Anesth Analg. 2012; 114(6):1323–9. PubMed PMID: 22467891. eng.
44. Abdallah FW, Chan VW, Brull R. Transversus abdominis plane block: a systematic review. Reg Anesth Pain Med. 2012;37(2):193–209. PubMed PMID: 22286518. eng.
45. Milone M, Di Minno MN, Musella M, Maietta P, Salvatore G, Iacovazzo C, et al. Outpatient inguinal hernia repair under local anaesthesia: feasibility and efficacy of ultrasound-guided transversus abdominis plane block. Hernia. 2013;17:749–55. PubMed PMID: 23160979. ENG.
46. Guirguis MN, Abd-Elsayed AA, Girgis G, Soliman LM. Ultrasound-guided transversus abdominis plane catheter for chronic abdominal pain. Pain Pract. 2013;13:235–8. PubMed PMID: 22734804. ENG.