8 Ultrasound Manifestation and Classification of Adenomyosis

Qing Dai and Jinhua Leng

At present, the commonly used diagnostic imaging examinations of adenomyosis are MRI and ultrasound. Ultrasound imaging is the first-line imaging method of choice for adenomyosis, because its practice is simple, easily repeatable, low cost, and with clear images and has no contraindications. Therefore ultrasound has been widely used in the diagnosis, classification, and follow-up observation of drugs and surgery after adenomyosis. The literature on ultrasound diagnosis of adenomyosis started in the 1980s. Transabdominal ultrasound was used to diagnose adenomyosis based on the sonographic uterine enlargement and asymmetric thickening of the anterior or/and posterior wall of the myometrium [1]. With the increasing use of transvaginal ultrasound (TVUS) after the 1990s, the high resolution of TVUS can give more detailed and comprehensive uterine features to diagnose adenomyosis with great certainty. Also, ultrasound examination has the advantages of simplicity, no radiation, easy repeatability, and low cost. At present, TVUS has been widely used in clinical practice and became the first and irreplaceable imaging examination for adenomyosis [2]. This chapter describes the ultrasound technology, imaging appearances, classification, differential diagnosis of adenomyosis, and advances in ultrasound imaging of adenomyosis.

8.1 Ultrasound Technology

Ultrasound for adenomyosis can be divided into different approaches: (1) transabdominal ultrasound, (2) transvaginal ultrasound, and (3) transrectal ultrasound.

Q. Dai (✉) · J. Leng
Department of Obstetrics and Gynecology, Peking Union Medical College Hospital, Beijing, China

M. Xue et al. (eds.), *Adenomyosis*, https://doi.org/10.1007/978-981-33-4095-4_8

8.1.1 Transabdominal Ultrasound

Subjects need to drink 500–1000 ml of water before the examination to fill the bladder. The ultrasound probe is a convex array probe, and the center frequency of the probe is 3.5 MHz. During the scan, the lower abdomen is exposed first, and an appropriate amount of coupling materials (usually ultrasound gel) is applied onto the abdomen. The probe is directly put on the skin of the abdominal wall for scanning. First, a longitudinal view of the uterus is scanned (Figure 8.1), and the uterine length, anteroposterior diameter, and endometrial thickness are measured. Then rotate the probe 90° for cross-section scan and measure the transverse uterine diameter; carefully observe any uterine lesions and both the adnexal areas. During the scanning, the probe is flexibly moved according to the lesions or the area of interest, with the scanning direction and angle changed to obtain the best image of the lesions, if any.

Transabdominal ultrasound scans have a wide range, flexible planes, and free scan angles and can display the full picture of the larger uterus. It is one of the commonly used ultrasound examination methods, but it is susceptible to factors, such as abdominal wall thickness, bladder filling degree, and intestinal flatulence.

8.1.2 Transvaginal Ultrasound

TVUS is ultrasonography with an ultrasound probe inserted into the vagina. It is one of the most commonly used ultrasound methods in gynecology. Subjects need to empty the bladder before the test. The examiner prepared a vaginal probe with a covering condom. For patients with vaginal bleeding, when TVUS is indeed necessary for diagnosis, the examiner should use a sterile condom. The subject routinely lays in a lithotomy position. If necessary, use a pillow to raise the hips or ask the examinee to place their hands under the hips to raise it. The ultrasound probe is for transvaginal use with a center frequency of 7.5 MHz.

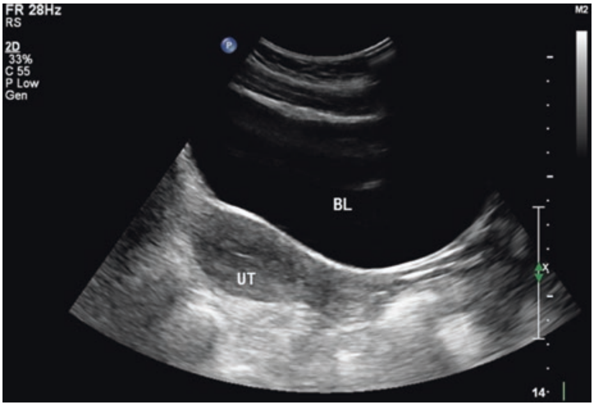


Fig. 8.1 Transabdominal ultrasound showing a normal longitudinal view of the uterus, *BL* bladder, *UT* uterus

During the scan, the longitudinal, transverse, and oblique planes of the pelvic structure are scanned using basic scanning techniques, such as rotation, tilt, and pumping. Measure the longitudinal uterine length, anterior and posterior wall diameters, and endometrial thickness on the longitudinal section of the uterus (Fig. 8.2); rotate the probe 90° to measure the transverse width of the uterus on the cross-section. Then carefully examine the uterus for any lesions and move the probe to the left or right side of the uterus to scan the left and right adnexal areas, including the bilateral ovaries and surrounding adnexa. During the scanning process, the probe should be flexibly moved, according to the lesion or the area of interest, and the scanning direction and angle should be changed to perform multi-section scanning to obtain the best image of any uterine lesion.

Due to the high frequency of transvaginal probe and its proximity to the pelvic organs and excellent image resolution, it can better display the structural characteristics and blood flow of uterine, ovarian, and pelvic masses and is not affected by bowel gas interference and abdominal wall sound attenuation. It is suitable for patients who can undergo a transvaginal examination. TVUS is superior to transabdominal ultrasound in the detailed observation of uterine lesions. However, although the transvaginal probe has a high frequency, its penetrating power is limited, and it is difficult to comprehensively observe a larger uterus, which needs to combine with a transabdominal ultrasound examination. TVUS cannot be performed on a virgin and vagina with congenital deformities, vaginal infection, and severe senile vaginal atrophy with stenosis.

8.1.3 Transrectal Ultrasound

Transrectal ultrasound is an approach to place an intraluminal probe in the rectum for an ultrasound examination. It is used for patients whose transabdominal ultrasound images are not clear but who cannot have a TVUS examination. Subjects need to empty the bowel and bladder before the transrectal examination. Generally, take laxatives the night before the examination and with an empty stomach on the

Fig. 8.2 TVUS shows a normal longitudinal section of the uterus

morning of the test. The subject takes a left lateral position with the left leg straight and the right leg flexed. Sometimes a supine lithotomy position can also be used. A transrectal probe is used, which can be the same probe used as the transvaginal probe.

After the probe is mounted with a latex condom, an appropriate amount of coupling agent should be added to the condom as a lubricant to facilitate the placement of the probe into the rectum. The scanning method and observation sequence are the same as those of transvaginal scanning.

8.2 Comparison of Transvaginal Ultrasound and Magnetic Resonance Imaging

The advantages of TVUS over magnetic resonance imaging (MRI) are mainly its universal applicability, economy, and easy repeatability. MRI uses quantifiable and specific diagnostic criteria to make the imaging diagnosis of adenomyosis more reliable; especially MRI can better show the endometrial-myometrial junctional zone (JZ). The JZ at T2W imaging showed that focal or diffuse thickening of the uterine wall is closely associated with adenomyosis [3]. Although the ultrasound does not show the JZ as distinctly as MRI, the ultrasound image can clearly show a series of sonographic features corresponding to the pathological changes of adenomyosis. It can be widely practiced in general medical office environments, and it is relatively cheap and well-tolerated and has no preparation required and no contraindications, particularly highly accurate in the hands of ultrasound experts. Therefore it becomes the preferred imaging examination for adenomyosis [4].

Compared with TVUS, the diagnostic accuracy of MRI was slightly higher in earlier studies. However, in recent years, with the continuous improvement of ultrasound technology and diagnostic level, the diagnostic accuracy of ultrasound for adenomyosis has been similar to that of MRI. The literature reported that both TVUS and MRI have high accuracy in the diagnosis of adenomyosis. Data from one study showed that the overall sensitivity of TVUS is 72% (95% CI 65–79%), and the specificity is 81% (95% CI 77–85%), while the overall sensitivity of MRI is 77% (95% CI 67–85%), and the specificity is 89% (95% CI 84–92%) [5]. Similar data from another study showed that TVUS had a sensitivity and specificity of 84% and 91.9%, respectively, while that of MRI were 88% and 94.6%, respectively. The accuracy rates of TVUS and MRI were 87.4% and 90.8% [4]. Therefore, the accuracy of TVUS and MRI in diagnosing adenomyosis is similar. Furthermore, the application of three-dimensional (3D) TVUS significantly improves the ability of ultrasound to display the uterine JZ and the diagnosis of adenomyosis.

8.3 Ultrasound Findings Reflect Histopathological Features

Ultrasound appearance of adenomyosis includes abnormal enlargement of the uterus, changes in the myometrial echogenicity, changes in the endometrial-myometrial JZ (changes in JZ), and abnormal uterine activity.

The ultrasound appearance of adenomyosis is based on its pathological changes. Histopathologically, adenomyosis is the invasion of the endometrial glands and stroma into the myometrium. Periodic bleeding occurs with the menstrual cycle, forming microcystic lesions, accompanied by reactive hyperplasia and hypertrophy of surrounding muscle fibers in the myometrium, forming a thickened fibrous muscular layer; the usual boundary between the endometrium and the muscular layer is destroyed, and the endometrium invades the inner muscle layer. The endometrium invades more than 2.5 mm to the underlying muscle layer or up to more than 25% of the myometrial thickness, forming adenomyosis.

Ultrasound images can clearly show the sonographic features that correspond to the pathological changes of adenomyosis and reflect the histological features [6], such as endometrial and myometrial injury leads to the growth of endometrial glands and stromal into the myometrium. Thus it gives rise to the ultrasound appearance of linear and bud-like hyperechoic islands below the endometrium.

According to the growth characteristics of adenomyosis, it can be divided into focal adenomyosis and diffuse adenomyosis. Histologically, if the endometrial glands and interstitials appear as a nodule, with its periphery surrounded by normal myometrium, this is a focal type of adenomyosis. When the endometrial glands in the myometrium are diffusely distributed, it is called diffuse adenomyosis. Adenomyoma is a subgroup of focal adenomyosis surrounded by a thick layer of myometrium [7].

8.4 Ultrasound Features of Adenomyosis

The main ultrasound features of adenomyosis include uterine spheroid enlargement, asymmetry thickening of the anterior or posterior myometrium of the uterus, myometrial heterogeneity, small cysts, and microcysts in the affected muscular layer. Besides, there may be fan-shaped sound shadows, moderate-high echogenic lines (linear stripes) or island nodules under the endometrium, unclear JZ, etc. Also, the color Doppler flow image shows blood flow signals in the adenomyosis lesion of the myometrium. Increased blood flow presents as penetrating vascularity. Whether it is diffuse adenomyosis or focal or adenomyoma, the heterogeneity in the lesion, rough, small cystic, or microcystic structures and the increase in color doppler flow imaging (CDFI) blood flow signals are common ultrasound manifestations of adenomyosis [6–12].

8.4.1 The Uterus Is Enlarged, with the Asymmetry of the Anterior and Posterior Walls of the Uterus

In diffuse adenomyosis, uterine enlargement is often manifested as a spherical enlargement (Figure 8.3a, b) with the enlargement of the entire uterine body, excluding the cervix. A normal uterus is inverted pear-shaped. When spherical, it shows that the anterior and posterior diameters increase significantly, there is no convex mass, and the uterine outline is not deformed. Even focal adenomyomas usually do not present with abnormal uterine contours like leiomyoma. Of course, the uterus with mild adenomyosis can be normal in size.

Myometrial thickening can be focal or diffuse. The former is a manifestation of focal adenomyosis. In diffuse adenomyosis, only a few cases show an increase in the anterior and posterior wall of the uterus and the fundus of the uterus (Fig. 8.4). The thickening of the anterior and posterior walls is asymmetric. Adenomyosis most often affects the uterine fundus and posterior wall area, less to the anterior wall, and rarely the uterine horn or the cervix. Therefore, the asymmetric thickening of the anterior and posterior uterine muscle layers is a common ultrasound manifestation of diffuse adenomyosis, and the posterior uterine wall and uterine fundal thickening are the most common (Fig. 8.5). Only a few manifest as anterior wall

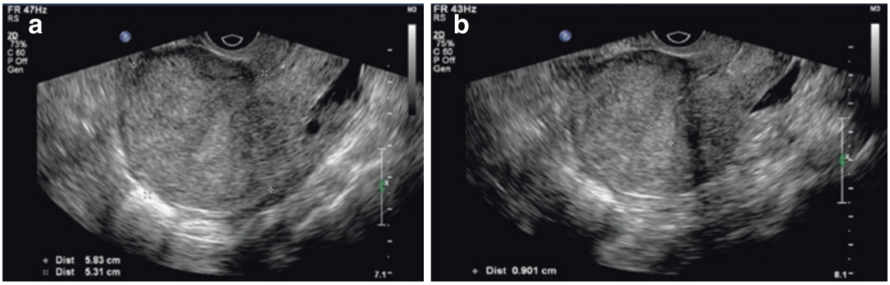
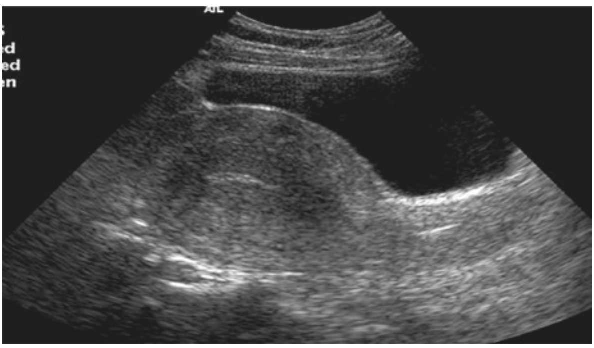


Fig. 8.3 (**a** and **b**): TVUS images, all of which are longitudinal sections of the uterus, and the uterus is spherically enlarged. (**a**) shows the measurement of the size of the uterus. (**b**) shows the measurement of the endometrium

Fig. 8.4 Transabdominal ultrasound image of diffuse adenomyosis, showing that the uterine body is diffusely and uniformly enlarged, that is, the uterine fundus, anterior wall, and posterior wall are all enlarged; the cervix is normal size



thickening (Fig. 8.6), and the majority of cases have a normal cervix, resulting in a significantly disproportionate size of the uterine body and the cervix.

In focal adenomyosis, the uterine myometrium is focally thickened and behaves similarly to uterine fibroids, but the boundary of the adenomyosis lesion is unclear (Figure 8.7a and b). Internal echo has the characteristics of adenomyosis, such as heterogeneity, rough, fan-shaped sound shadow, small cysts or microcysts, etc.; some focal lesions may have an easily distinguished boundary, and they are called adenomyoma (Fig. 8.8), but the border of adenomyoma is still less precise compared with that of uterine fibroid.

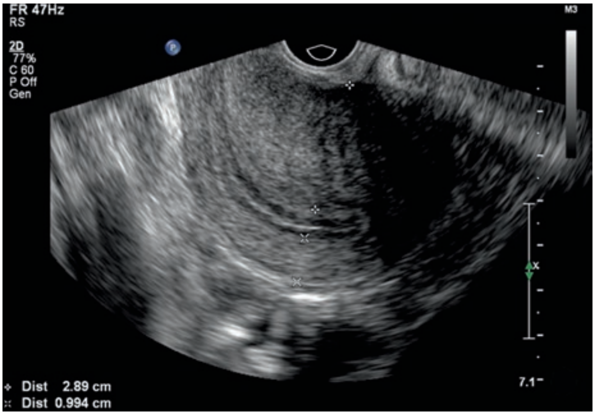


Fig. 8.5 TVUS image of diffuse adenomyosis, showing increased asymmetry of the anterior and posterior wall of the uterus. The uterus shows mainly the thickness of the posterior wall. The thickness of the posterior wall is 2.89 cm, while the anterior wall is only 0.99 cm

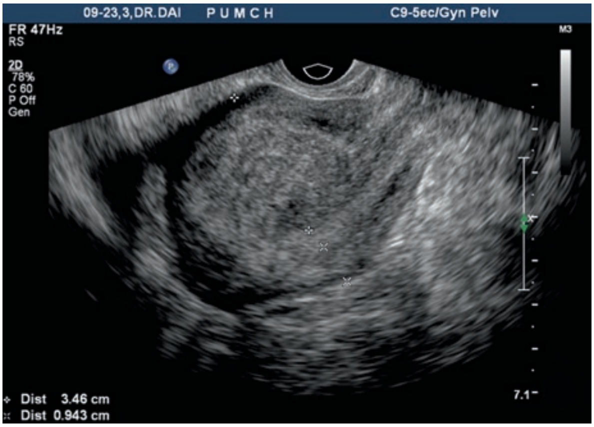


Fig. 8.6 TVUS image of diffuse adenomyosis showing increased asymmetry of the anterior and posterior wall of the uterus, the uterus is anteverted; the anterior wall of the uterus has a thickness of 3.5 cm and the posterior wall 0.9 cm

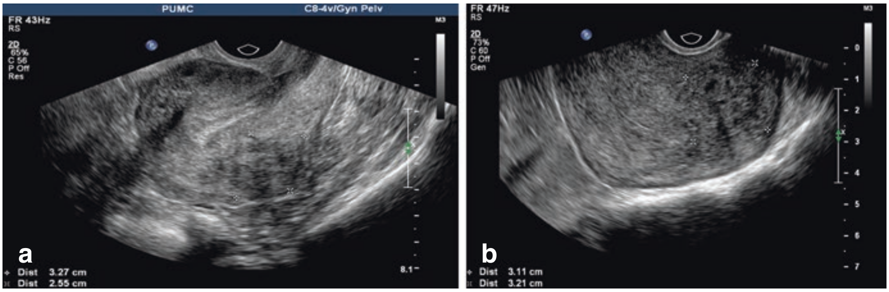


Fig. 8.7 (**a**) TVUS image of focal adenomyosis. The uterus is anteverted, showing a focal enlargement of the posterior wall of the uterus, the range of the lesion is 3.3 cm × 2.6 cm, the boundary of adenomyoma is unclear, and the internal echo is heterogeneous with partial pencil-like sound shadow (**b**) TVUS image of focal adenomyosis. The uterus is retroverted, showing a focal increase in the posterior wall of the uterus near the fundus of the uterus. The size of the lesion is 3.2 cm × 3.1 cm. It is difficult to distinguish a clear border of the entire lesion

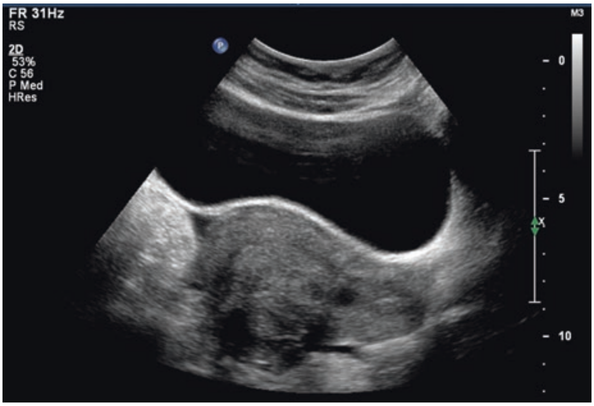


Fig. 8.8 Transabdominal ultrasound image of focal adenomyoma. The uterus is anteverted, showing that the posterior wall of the uterus is focally enlarged, and the boundary of the lesion is unclear. The border of the lesion can still be distinguished, because it protrudes towards the surface of the uterus. There are heterogeneous inside the lesion

8.4.2 Heterogeneity of the Myometrium

Regardless of diffuse or focal adenomyosis, the heterogeneity of the affected myometrium is the most common ultrasound manifestation of adenomyosis [13]. The unevenness is mainly due to the echogenic changes of the uterine myometrium and low echo alternating with hyperechoic stripes or nodules; the arrangement is disordered, making the uterine texture significantly heterogeneous and rough (Figure 8.9a, b), similar to the manifestation of liver cirrhosis in end-stage liver disease. Meanwhile, multiple linear sound shadows also cause heterogeneity. The degree of echo unevenness also reflects the severity of adenomyosis to a certain extent.

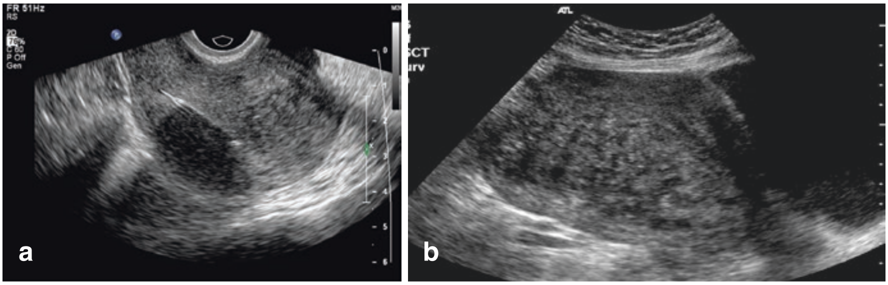


Fig. 8.9 (**a**) TVUS image of adenomyosis. The uterus is retroverted. The picture shows the echotexture of the posterior uterine muscle layer changes, with uneven echo and thicken wall; meanwhile, the intrauterine cavity shows the high echoes of the Mirena IUCD, and the sound shadow behind it. The echoes of the myometrium of the anterior wall of the uterus are not seen clearly (**b**) Transabdominal ultrasound image of adenomyosis. The uterus is anteverted; the picture shows that the echo of the posterior wall of the uterus is obviously uneven and rough, and the hypoechoic stripes and hyperechoic stripes or nodules alternately exist. The arrangement is disordered, and the posterior wall is significantly thicker than the anterior wall

8.4.3 Small Cysts or Microcysts in the Affected Myometrium

Cyclic bleeding of the ectopic endometrial glands in the myometrium can lead to the formation of small cysts or microcysts in the myometrium. Cysts are usually 1–5 mm in diameter and are generally in the form of non-echoic areas (Figure 8.10a, b, and c). Because the fluid in the sac is old blood, small cysts can also appear as hypoechoic cysts. By reducing the field of view and enlarging the ultrasound image, the display effect of these cysts can be improved. Due to the active endometrial tissue and inflammatory response around the cyst, there is a hyperechoic rim around the cyst, appearing like a thick cyst wall (Fig. 8.11).

Small cysts in the myometrium are very specific ultrasound features of adenomyosis. As early as the beginning of this century, research by Bazot et al. [13] showed that small uterine myometrial cysts are the most sensitive and specific criteria for ultrasound diagnosis of adenomyosis. More recent studies [14] have shown that the most specific ultrasound feature of TVUS for the diagnosis of adenomyosis is myometrial cysts (98% specificity), and the most sensitive ultrasound feature is the heterogeneity of the myometrium (88% sensitivity). Besides, the linear echoes perpendicular to the endometrium under the intima can be seen filled with liquid and present as a linear anechoic zone [7].

8.4.4 Fan-Shaped Sound Shadow in the Uterus

The other characteristic ultrasound features, which is as important as the myometrial heterogeneity, is a fan-shaped sound shadow caused by the changes of the texture of the uterine myometrium, also known as the shutter sign, multiple linear or pencil-shaped sound shadow [7]. In adenomyosis, the hyperechoic and hypoechoic

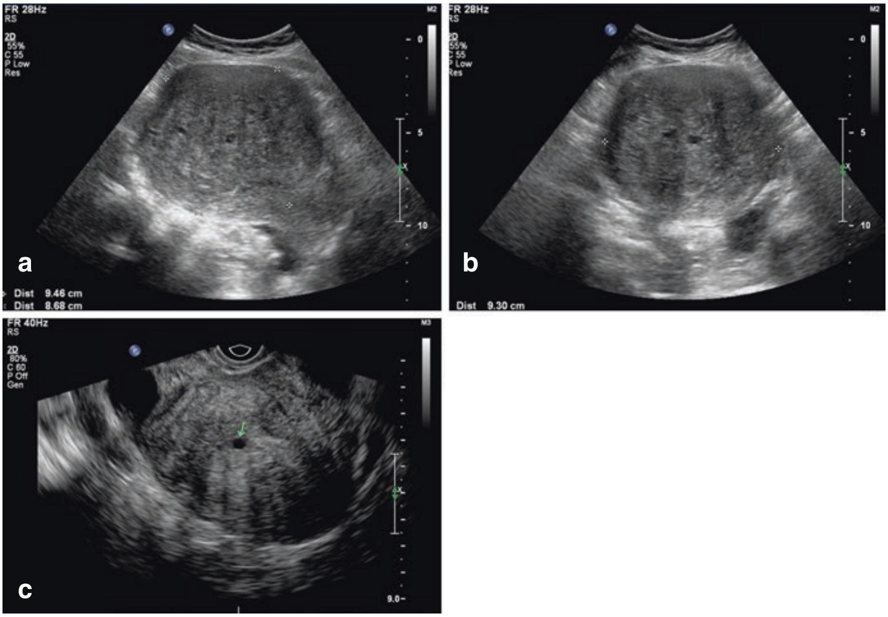
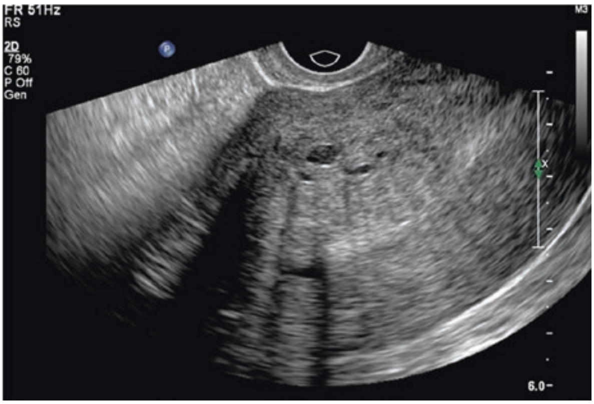


Fig. 8.10 (**a** and **b**) Transabdominal ultrasound images of diffuse adenomyosis, the uterus is anteverted, which shows that the anterior uterine muscle layer is significantly thickened, and the echo is heterogeneous. Multiple small anechoic areas scattered in the lesion are visible. (**c**) TVUS image of adenomyosis. The uterus is anteverted. It shows that the anterior wall of the uterus is thickened, and the echo is uneven. Several small anechoic areas (pointed by arrows) are visible

Fig. 8.11 TVUS image of adenomyosis. The uterus is anteverted, showing that the anterior wall of the uterus is thickened, and the echo is significantly uneven. There are several small anechoic areas and hyperechoic rim around the anechoic area



areas appear alternately and disorderly in the uterine myometrium. The normal myometrial echotexture disappears, and the echo becomes heterogeneous and rough. Many vertical and thin radially fan-shaped sound shadows (Figure 8.12a-c) are identified.

Although leiomyomas can have fan-shaped sound shadows like adenomyosis, the sound shadows of uterine fibroids are more likely to be caused by dense calcification or by attenuation of fibrous components or lateral sound shadows of the cystic areas. The width of the sound shadow varies, as shown in Fig. 8.13. A large leiomyoma can sometimes completely obscure the ultrasound manifestations of adenomyosis, at which point MRI is needed to help determine the presence of adenomyosis.

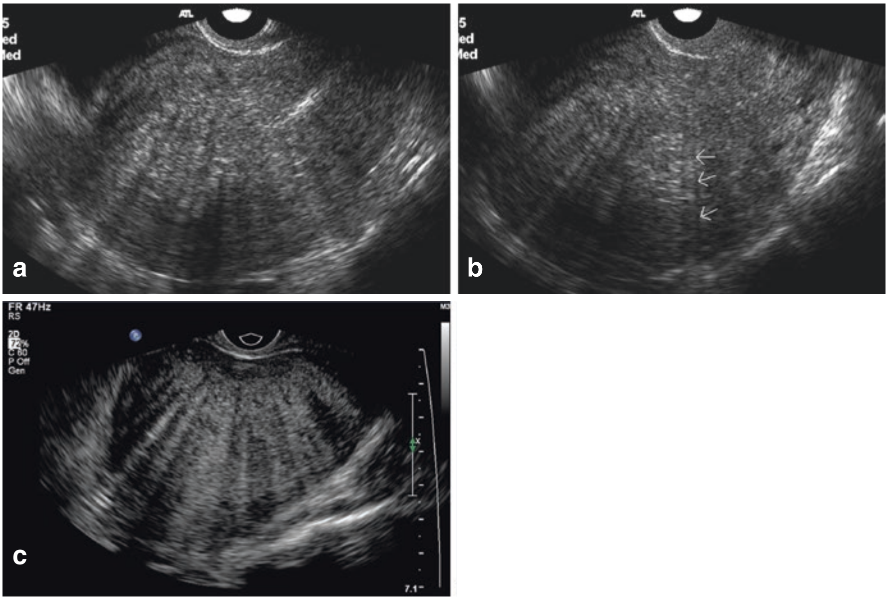


Fig. 8.12 (**a**-**c**): TVUS images of adenomyosis show that in addition to the enlargement of the uterus and uneven echos of the uterine myometrium, fan-shaped sound shadows can be seen in the uterus and appear as straight and thin streaks or pencils-like sound shadows. These sound shadows are arranged in a fan-shaped or jalousie-like arrangement

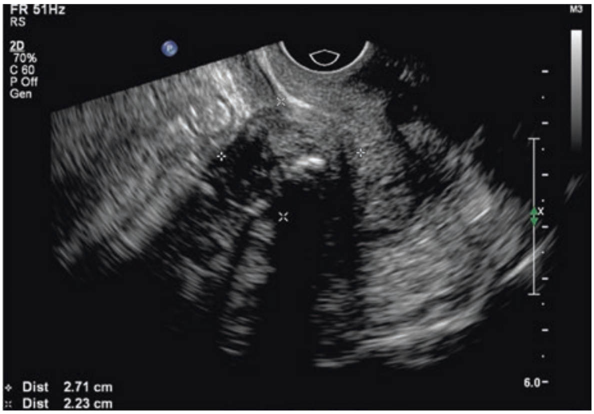


Fig. 8.13 TVUS image of uterine fibroids, showing that the acoustic shadow of uterine fibroids is different from that of adenomyosis. The fibroid image shows a well-defined hypoechoic lesion in the uterus, sometimes with the hyperechoic lesion, and a wide range of sound shadows behind it

8.4.5 Linear, bud, or Island-like Hyperechoic Nodules under the Endometrium

In adenomyosis, the endometrial-myometrial demarcation is unclear (Figure 8.14a), or hyperechoic linear, bud-like echo stripes, or island nodules can be seen in the region of the endometrial zone. Uterine adenomyosis is where the glands and stroma of the endometrium invade the myometrium in an "inside-out" order. The above manifestations represent the endometrial tissue extending directly into the myometrium, with linear stripes or island nodules extend into the muscular layer from the endometrial boundary (Figure 8.14b). The linear endometrial streaks are the most special ultrasound feature of adenomyosis and have high diagnostic accuracy [7].

8.4.6 The Endometrial-Myometrial Junctional Zone (JZ) Is Thickened, Irregular, Interrupted or Difficult to Distinguish

The endometrial-myometrial JZ is a muscle layer structure, which is a transitional region between the endometrium and the muscle layer. It consists of longitudinal and circular, tightly arranged smooth muscle fibers. The blurred boundary of the endometrial-myometrial boundary in the adenomyosis is mainly due to changes in the uterine JZ caused by the endometrial invasion. MRI has a typical feature for the thickening of the JZ, but it is still difficult to measure the JZ accurately on ultrasound. However, in the recent 10 years, with 3D ultrasound technology and volume contrast imaging (VCI) and other new ultrasound technologies increasingly applied in clinical practice, ultrasound has been able to evaluate the uterine JZ reliably [11]. Kepkep et al. 2007 [12] reported that 3D TVUS makes the display of JZ clearer, and the unclear boundary of JZ has a high specificity (82%) for the diagnosis of adenomyosis. Exacoustos et al. 2011 [14] reported that on 3D

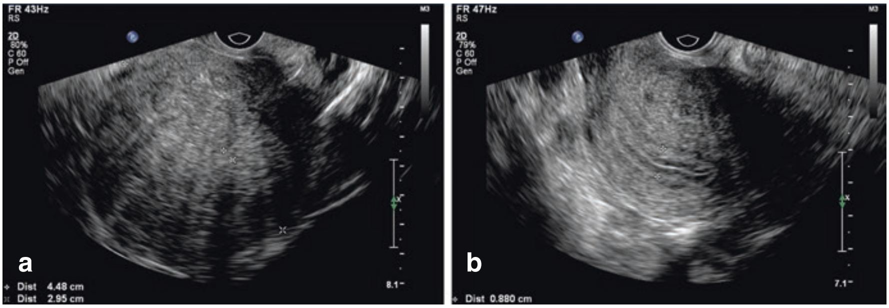


Fig. 8.14 (**a** and **b**) TVUS images of adenomyosis. (**a**) presents an anteverted uterus. The image shows diffuse adenomyosis; the anteroposterior walls are thickened, the echoes are significantly uneven, the fan-shaped sound shadow, and the endometrial-myometrial boundary is unclear, making it difficult to distinguish the endometrial border. (**b**) presents a posterior uterus, and the image shows linear streaks visible under the endometrium

TVUS, the maximum thickness of the JZ (JZ max) ≥ 8 mm or the difference between the maximum and minimum JZ thickness (JZ diff) ≥ 4 mm might be possibly adenomyosis.

8.4.7 Increased Blood Flow Signal in the Lesion, with Penetrating Vascular Feature

In adenomyosis, due to myofibrosis and hypertrophy of the uterine myometrium, blood vessels in the uterine myometrium have also generally increased. CDFI showed increased blood flow signals in the uterine myometrial area (Figure 8.15a, b, c, and d); the blood flow presents as a penetrating blood flow (straight blood vessels are present), and more tortuous blood vessels pass through the affected myometrium [8]. This feature is also seen in angiography.

The area of increased blood flow signals in the myometrium can reflect the extent and distribution of adenomyosis. At the same time, the CDFI manifestations of adenomyosis can also help distinguish between adenomyosis and uterine fibroids [15].

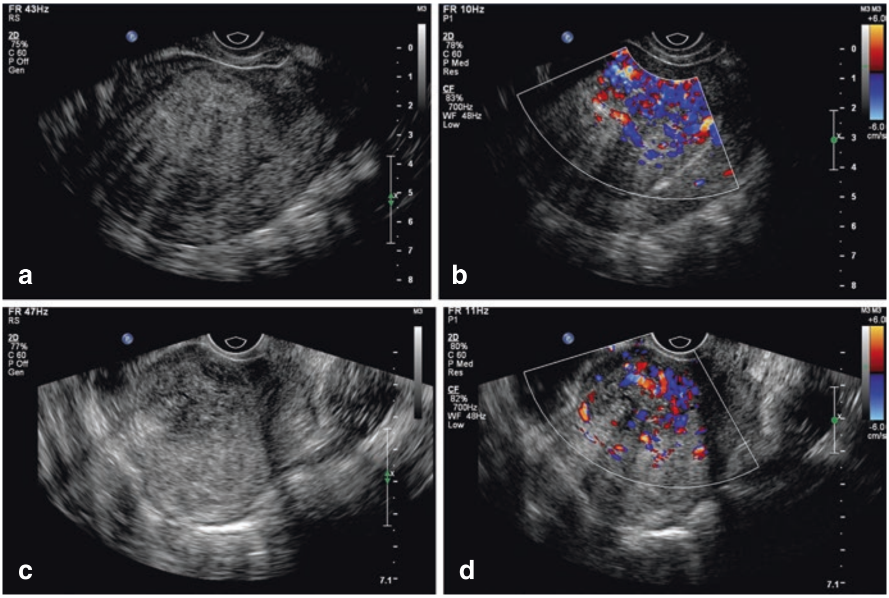


Fig. 8.15 **a** and **b** TVUS images of diffuse adenomyosis of the anterior wall of the uterus, the uterus is anteverted. (**a**) is a grey-scale ultrasound image showing a marked thickening of the anterior wall of the uterus, significantly uneven echoes, and fan-shaped sound shadows. (**b**) is a color doppler flow imaging (CDFI). The CDFI image shows abundant myometrial blood vessels with increased blood flow signals. (**c** and **d**) TVUS images of focal adenomyosis, the uterine position is also anterior in this case. (**c**) is a grey-scale ultrasound image showing focal lesions with uneven echoes visible in the anterior wall uterine myometrium, and the border is unclear. (**d**) is a CDFI image showing an increase in blood flow signals within the lesion

The CDFI blood flow performance of the two is significantly different. Focal adenomyosis/adenomyoma is a penetrating blood flow mode. In contrast, the typical blood flow pattern of uterine fibroids is a peripheral blood flow mode, which is caused by pressure displacement of blood vessels at the pseudocapsule of the fibroid.

8.4.8 Ultrasound Scanning Skill for Adenomyosis

1. There are complementary imaging effects of the transabdominal probe and transvaginal probe. The transabdominal examination can make a more comprehensive observation of a large uterus. When the uterus is large, high-frequency transvaginal probes can hardly show the uterine muscle layer of the entire posterior wall. At this time, low-frequency transabdominal ultrasound probes should be used. Besides, low-frequency probes can also improve the display of endometrial boundaries.

2. On a single static ultrasound image of adenomyosis, it is sometimes difficult to identify changes in some echogenicities and fan-shaped sound shadows. Using the frame-by-frame playback (cine clips, movie editing) function after the freeze-frame image, these ultrasound features of adenomyosis can be better observed, especially for the uterine JZ layer non-uniformity and fan-shaped sound shadow. Observations are often visible when playing back uterine images frame by frame. It is also easier to observe the continuity of the echo stripes in the endometrial-myometrial JZ through playback.

8.4.9 Ultrasound Uterine Sliding Sign

When using a transvaginal probe, gently push the uterus and ovaries; they slide freely and are positive for sliding signs, indicating that these pelvic organs are non-adhesive; when they are not free to move, they are negative for sliding signs, meaning that the uterus and ovaries have adhesions or may have pelvic endometriosis, etc. [16].

In adenomyosis, if the outer myometrial layer is involved, the serosal layer may be involved as well. In order to determine the involvement of the uterine serosal layer, the uterus should be recorded for slippage or adhesion to the intestine during ultrasound examination; a negative uterine sliding sign indicates adenomyosis may involve the uterine serosa [17].

Of course, the importance of the ultrasound uterine sliding sign lies in the judgment of the entire uterus and pelvic adhesions and whether the adenomyosis is accompanied by deep infiltrating endometriosis at the same time. Because adenomyosis may not be a single manifestation with endometriosis, there may be other endometriosis, such as ovarian endometriosis (chocolate cysts), deep infiltration endometriosis, etc. Ovarian cysts are easier to find by ultrasonography, while deep infiltrating endometriosis may be to ignore during ultrasonography. Careful scanning is required during the examination. In the presence of an ovarian cyst, the application of sliding signs can also detect any adhesion of the cyst to the uterus and surrounding organs.

8.4.10 Ultrasound Classification of Adenomyosis

According to the ultrasound appearances of adenomyosis, they are mainly divided into two types: diffuse adenomyosis and focal adenomyosis.

The ultrasound features of focal adenomyosis can be divided into two subtypes—adenomyoma and cystic adenomyoma. The classification of ultrasound imaging is closely related to the clinical and histopathology of adenomyosis. Histologically, the endometrial glands and interstitial tissue of adenomyosis are diffusely distributed in the muscular layer. When the endometrial glands and interstitials are localized and nodular, with the periphery surrounded by normal myometrium, this lesion is called focal adenomyosis. Both the adenomyoma and cystic adenomyoma are surrounded by a thick layer of the myometrium, with cystic adenomyoma showing cystic changes in the central area of the lesion.

8.4.11 Diffuse Adenomyosis

The posterior uterine wall, uterine fundus, or anterior wall is diffusely involved by adenomyosis. The ultrasound of diffuse adenomyosis is enlarged uterus, and the anterior and posterior walls are often asymmetric. The echogenicity of the affected uterine myometrium is heterogeneous and rough. Fan-shaped sound shadow is common, that is, there are more linear acoustic shadows in the uterine myometrium, and sometimes small cysts (< 5 mm) or microcysts can be seen in the affected myometrium. The boundary between the endometrium and the myometrium is unclear, and high-frequency transvaginal ultrasound sometimes shows moderate-high linear or nodular echo in the JZ zone; CDFI shows increased blood flow signals in the affected myometrium.

8.4.12 Focal Adenomyosis

The focal adenomyosis shows local thickening of the myometrium, heterogeneity, roughness, and fan-shaped sound shadows, sometimes small cysts or microcysts, CDFI seeing blood flow signals in the area of the lesion, and the flow signal can be increased. These ultrasound features of focal adenomyosis are consistent with that of diffuse adenomyosis; there is also an unclear border of the focal lesion (Figure 8.7a, b), and the JZ between the endometrium and the surrounding myometrium is blurred and difficult to distinguish the boundary.

Uterine adenomyoma refers to the focal adenomyosis with relatively clear boundaries. The lesion has a distinguishable border, but it is still not clear enough compared with that of the uterine fibroid (Fig. 8.8).

The cystic adenomyoma is a rare type of focal adenomyosis. It is manifested with old blood-filled cysts in the adenomyoma lesion, and the maximum diameter of the cyst usually exceeds ≥1 cm. Clinical and ultrasound examinations are easily misdiagnosed as residual blood in a uterine horn or cystic changes in a fibroid.

According to the age of onset, the disease can be divided into adolescent and adult types. From the literature [18], it pointed out the diagnostic criteria for adolescent cystic adenomyosis: (1) age ≤ 30 years; (2) the size of the cyst is generally greater than or equal to 1 cm; the cyst cavity is independent of the uterine cavity and the surrounding hyperplastic smooth muscle tissue; and (3) early severe dysmenorrhea. In contrast, the diagnostic criteria for adult type are vague; Kriplani et al. [19] pointed out that the age of onset of adult type is >30 years, the symptoms are similar to typical adenomyosis, and there is a history of uterine surgical trauma.

The size of cystic adenomyoma is mostly 3 to 5 cm in diameter and is located at the posterior wall of the uterus and cornua. Sometimes the lesion is deep and challenging to find with the naked eye, but ultrasound examination may determine the location of the lesion. A cut opened lesion can show chocolate-like fluid flowing out, the wall thickness of the capsule is about 5 to 8 mm, and the diameter of the capsule cavity is mostly 1 to 3 cm, which is not connected with the uterine cavity. The endometrial glands and their interstitium form the cyst wall, which is surrounded by a hypertrophic uterine muscle, forming the cystic adenomyoma.

On the contrary, ultrasound manifestation of cystic adenomyosis showed that it is often located in the uterine myometrium near the cornua of the uterus. There is no clear border, and the uterus is enlarged to varying degrees. There is an anechoic area in the center or hypoechoic area, surrounded by thick hypoechoic areas (Figure 8.16a–d); CDFI can see the sparse star-shaped blood flow signals in the internal solid area [18–20].

Cystic adenomyosis should be distinguished from residual uterine hemorrhage and cystic fibroids. For bleeding in a cornual area, the ultrasound shows that the uterus and uterine cavity are relatively normal, only with a cystic echo in the muscle layer near the uterine cornua. Differentiating it from cystic fibroids can sometimes be difficult. The ultrasound performance of the two is similar and easy to misdiagnose. The main points of identification are a clear boundary of uterine fibroids, and CDFI shows circular blood flow signals around the lesion. In contrast, cystic uterine adenomyoma is unclear, and the peripheral blood flow signal is not apparent.

8.4.13 Differential Diagnosis of Adenomyosis

Uterine adenomyosis needs to be distinguished from uterine fibroid, myometrial contraction, myometrial invasion due to endometrial cancer, and myometrial vascular abnormalities.

8.4.13.1 Uterine Fibroids

Focal adenomyosis and uterine leiomyoma have similar ultrasound performance and need to be identified. It is necessary to distinguish the two accurately. The main

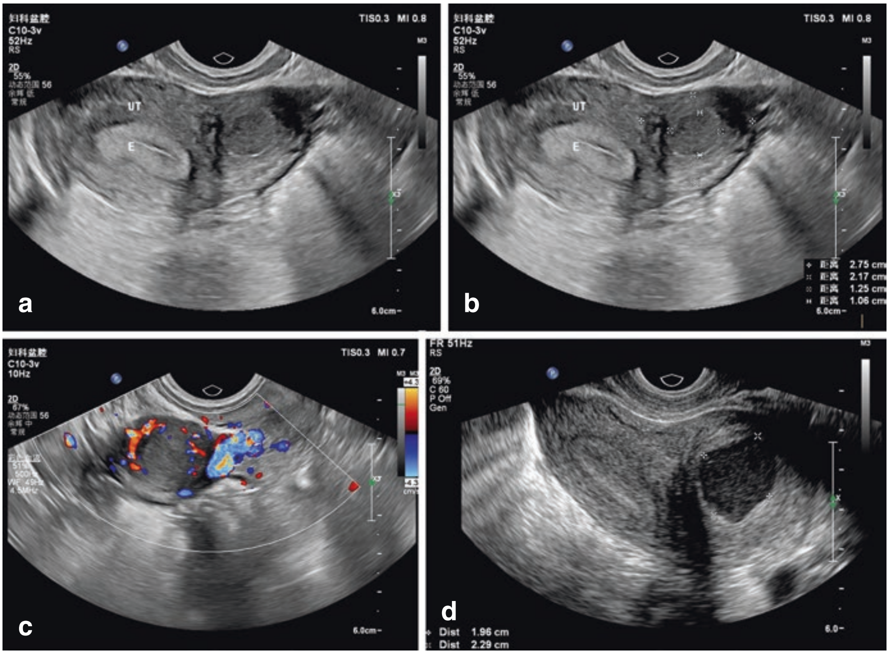


Fig. 8.16 (**a**-**d**): Transabdominal and transrectal ultrasound images of cystic adenomyosis. (**a**-**c**) are transabdomianal images with transvaginal probe placed on the abdomen. (**a** and **b**) show a mixed echo mass at the left wall of the uterus near the left corner of the uterus. The central area of the mass is a non-echo area with poor sound transmission. Thick echogenic areas are surrounding the anechoic area. In the hypoechoic area, the size of the entire lesion is 2.8 cm × 2.2 cm, and the size of the non-echo area is 1.3 cm × 1.1 cm. The boundary between the lesion and the normal muscular layer is unclear. (**c**) is a CDFI image of this case, showing a surrounding blood flow signal around the lesion. (**d**) is a transrectal ultrasound image of this case at the time of re-examination 10 months later. It can be seen that the frost glass in the non-echoic area of the center of the lesion is more typical, with a size of 2.3 cm × 2.0 cm

points of adenomyosis and uterine leiomyoma are their borders, features of small cysts, and internal echoes as well as the appearance of CDFI. Uterine fibroids have pseudocapsules, which appear as well-defined masses, sometimes in concentric circles or swirls. The echogenicities of uterine fibroids vary widely, from uniform hypoechoic, iso-echogenic, or high echogenic to unevenly mixed echoes and/or hyperechoic (calcification), etc.; the blood flow of fibroids is mainly peripheral (Figure 8.17a, b).

In contrast, the border of uterine adenomyoma is unclear, and it is mostly hypoechoic. The blood flow is dominantly penetrating blood flow (Figure 8.18a, b). CDFI plays a crucial role in distinguishing uterine fibroids from adenomyomas. Chiang et al. 1999 [15] reported that 88% of adenomyosis is penetrating blood flow, and 87% of leiomyomas are peripheral blood flow. When identification is difficult, contrast-enhanced ultrasound can help define the diagnosis. Also, leiomyoma and adenomyosis both have a fan-shaped sound shadow. However, the sound shadow of uterine fibroids tends to be uneven and irregular, and the sound shadow of

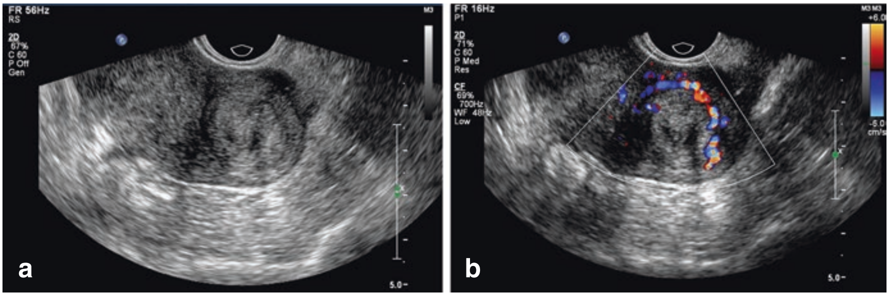


Fig. 8.17 (**a** and **b**) TVUS images of uterine fibroids, the uterus is retroverted. (**a**) is a grey-scale ultrasound image showing the hypoechoic lesion visible at the fundus of the uterus, with regular morphology and clear boundaries; (**b**) is a CDFI image showing a typical circular blood flow signal around the uterine lesion

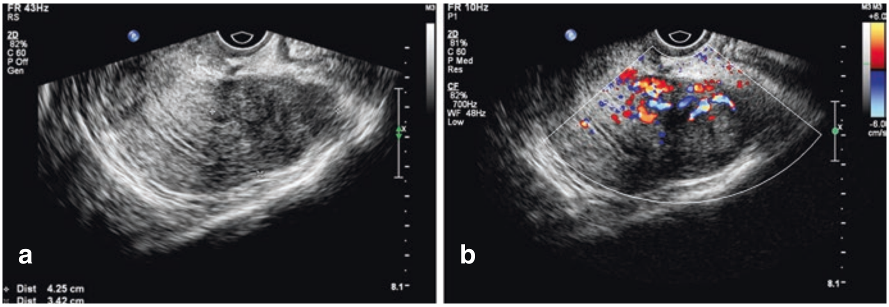


Fig. 8.18 (**a** and **b**): TVUS images of focal adenomyosis in the posterior wall of the uterus, the uterus is retroverted. (**a**) is a grey-scale ultrasound image showing a hypoechoic area seen in the posterior wall of the uterus, protruding towards the surface of the uterus, with unclear boundaries, and the echo in the lesion is significantly uneven. (**b**) is a CDFI image showing a typical penetrating blood flow signal into the uterine lesion

adenomyosis tend to be even and fine. It should be noted that uterine fibroids and adenomyosis are common diseases and often coexist.

8.4.13.2 Myometrial Contraction

The contraction of the myometrium can sometimes be expressed as a focal hypoechoic mass in the myometrium, which can be mistaken for uterine fibroids or focal adenomyosis, requiring the attention of young physicians to make a diagnosis. The local contraction of the myometrium can be distinguished from the myometrial lesion by its short-term nature, and it can be identified by re-examination by ultrasound in about half an hour later.

8.4.13.3 Myometrial Infiltration of Endometrial Cancer

Endometrial cancer may also be irregular when the myometrium invades the muscular layer and needs to be identified. Endometrial cancer is characterized by endometrial thickening and abundant local blood flow. When invading the myometrium, the uterine JZ under the endometrium is destroyed, like adenomyosis. CDFI shows the local increase in endometrial blood flow. According to the thickening of the endometrium, the affected JZ and the muscle layer have a more clumpy effect, unlike the thin stripes and small island nodules of adenomyosis. MRI evaluation and endometrial biopsy can confirm the diagnosis [21].

8.5 Application of New Ultrasound Technology in the Diagnosis and Treatment of Adenomyosis

8.5.1 Application of 3D Ultrasound

The most important value of 3D ultrasound in diagnosing adenomyosis is that it can more intuitively show the endometrial-muscular JZ, which can diagnose adenomyosis early, because the uterine JZ is the earliest ectopic endometrial lesion. The appearance shows either an enlarged or discontinued JZ observed by the 3D ultrasound scan. The application of 3D ultrasound post-processing technology (VCI technology) can improve the contrast of the image and better display the JZ [22].

3D ultrasound features of adenomyosis also include irregular bands, thickening, interruptions, sub-endometrial hyperechoic lines, and island nodules in the JZ similar to the 2D ultrasound features [3, 11, 14, 22].

8.5.2 Application of Elastography

Elastography has been used in the diagnosis of many organs and systems. The literature shows that the sensitivity and specificity of elastography in diagnosing adenomyosis is 89.7% and 92.9%. The stiffness and hardness of the adenomyosis are much higher than that of a normal myometrium, which is closely related to the fibrosis of the adenomyosis tissues. The lesional stiffness detected by elastography in the adenomyosis correlated with hormone receptor expression levels, which is also related to the severity of pain symptoms [23, 24]. However, Zhang et al. 2019 [25] showed that elastography did not distinguish between fibroids and adenomyosis. It can be seen that the application of elastography in adenomyosis requires further research, and it is still difficult to use it for routine diagnosis [25].

New Advances in the Diagnosis of Adenomyosis by Ultrasound.

More and more research evidence show that adenomyosis is closely related to infertility. Although the mechanism is unknown, early diagnosis and evaluation can help to preserve female reproductive function. The more extensive ultrasound features of adenomyosis, the more likely it indicates a higher risk of infertility. Some scholars have proposed a scoring system to assess the severity of adenomyosis, which specifically corresponds to the severity of ultrasound signs and guides for individualized treatment [26].

Many studies have pointed out the need to clarify the role of changes in the uterine JZ in the diagnosis of adenomyosis and emphasized the need to obtain good images of the zone through 3D transvaginal ultrasound [3, 11, 14, 22]. 3D ultrasound may also need to be involved in clinical practice to make an early diagnosis of adenomyosis and hopefully to treat the adenomyosis and conserve fertility in its early development.

Ultrasound diagnosis for adenomyosis depends to some extent on the experience of the examiner. In recent years, some scholars have proposed the need for standardized training of ultrasound residents and to improve the diagnosis of adenomyosis through standardized pattern recognition learning. They have also suggested the use of ultrasound feature checklists to promote pattern recognition learning [22, 27].

European and American ultrasound scholars discussed it in a meeting and reached a consensus recommendation. They proposed a standardized and unified classification and reporting system for adenomyosis [28]. The consensus recommends that ultrasound reports for adenomyosis should include seven points:

1. According to the 2015 publication of the Uterine Ultrasound Evaluation Research Group (MUSA), the consensus of MUSA established the standardized terms, definitions, and measurements of the ultrasound characteristics of the uterine myometrium and uterine mass, to set up the criteria for identifying adenomyosis [29].
2. The location of the lesion (anterior wall, posterior wall, left side wall, right side wall, outer sidewall, and uterine fundus).
3. Focal or diffuse lesions: more than 25% of myometrial involvement of the uterine body is classified as diffuse adenomyosis; if it is difficult to distinguish between focal and diffuse lesions, the lesion should be reported as diffuse adenomyosis; if there are both diffuse and focal adenomyosis in different parts of the uterus, it is called "hybrid adenomyosis." Focal adenomyosis is defined as an adenomyoma of the uterus when it is surrounded by a thick layer of the myometrium, with relatively clear boundaries.
4. The definition of cystic adenomyoma is the presence of measurable cysts inside the adenomyosis. Generally, the maximum diameter is at least 2 mm, which is always measurable. It should be reported if the cysts are present in all types of adenomyosis (focal, diffuse, mixed adenomyosis, and adenomyoma).
5. Assessing the involvement of various layers of the uterus, including the uterine JZ, the uterine muscle layer, and the serosa layer.
6. Degree of the disease (adenomyosis affects uterine volume < 25%, 25–50%, >50%): subjective assessment of disease severity (mild <25%, moderate 25–50%, or severe >50% adenomyosis).
7. The size of the lesion: for diffuse lesions, there is a need to measure the thickness of the anterior and posterior wall of the uterus. For focal lesions, at least the maximum diameter of each lesion should be measured. The three diameters of the lesion should be recorded when conducting research.

The consensus statement [28] issued by MUSA in 2015 suggested that standardized terms should be used to describe ultrasound images of adenomyosis. However, it did not guide the classification or degree of adenomyosis. UOG in 2018 issued this classification, and the reporting system [29] helps to compensate for the deficiency, which is worth our attention. Of course, the clinical application of this classification and reporting system needs further confirmation and improvement.

To summarize, ultrasound is the clinically preferred imaging method for adenomyosis, and transvaginal ultrasound is the main ultrasound examination for diagnosing adenomyosis. In most cases, transvaginal ultrasound can more accurately diagnose adenomyosis, especially when there are multiple ultrasound features of adenomyosis; ultrasound has higher effectiveness in diagnosing adenomyosis. The 2D ultrasound playback function and advanced ultrasound technology, such as the reconstructed image of 3D ultrasound, can supplement the deficiency of conventional ultrasound and further improve the diagnostic efficacy of ultrasound for adenomyosis.

References

1. Bohlman ME, Ensor RE, Sanders RC. Sonographic findings in adenomyosis of the uterus. AJR Am J Roentgenol. 1987;148(4):765–6.
2. Tan J, Yong P, Bedaiwy MA. A critical review of recent advances in the diagnosis, classification, and management of uterine adenomyosis. Curr Opin Obstet Gynecol. 2019;31:212–21.
3. Rasmussen CK, Hansen ES, Dueholm M. Two- and three-dimensional ultrasonographic features related to histopathology of the uterine endometrial-myometrial junctional zone. Acta Obstet Gynecol Scand. 2019;98(2):205–14.
4. Karamanidis D, Nicolaou P, Chrysafis I, et al. Transvaginal ultrasonography compared with magnetic resonance imaging for the diagnosis of adenomyosis. Ultrasound Obstet Gynecol. 2018;52(4):555–6.
5. Champaneria R, Abedin P, Daniels J, Balogun M, Khan KS. Ultrasound scan and magnetic resonance imaging for the diagnosis of adenomyosis: systematic review comparing test accuracy. Acta Obstet Gynecol Scand. 2010;89:1374–84.
6. Van den Bosch T, Van Schoubroeck D. Ultrasound diagnosis of endometriosis and adenomyosis: state of the art. Best Pract Res Clin Obstet Gynaecol. 2018;51:16–24.
7. Cunningham RK, Horrow MM, Smith RJ, et al. Adenomyosis: A Sonographic diagnosis. Radio Graphics. 2018;38(5):576–1589.
8. Konrad J, Merck D, Wu JY, et al. Improving ultrasound detection of uterine Adenomyosis through computational texture analysis. Ultrasound Q. 2017;34(1):29–31.
9. Tellum T, Nygaard S, Skovholt EK, et al. Development of a clinical prediction model for diagnosing adenomyosis. Fertil Steril. 2018;110(5):957–64. e3
10. Pinzauti S, Lazzeri L, Tostic C, et al. Transvaginal sonographic features of diffuse adenomyosis in 18–30-year-old nulligravid women without endometriosis: association with symptoms. Ultrasound Obstet Gynecol. 2015;46:730–6.
11. Votino A. Van den Bosc h T, Installé AJF et al. optimizing the ultrasound visualization of the endometrial-myometrial junction (EMJ). Facts Views Vis Obgyn. 2015;7(1):60–3.
12. Kepkep K, Tuncay YA, Goynumer G, Tutal E. Transvaginal sonography in the diagnosis of adenomyosis: which findings are most accurate? Ultrasound Obstet Gynecol. 2007;30:341–5.
13. Bazot M, Cortez A, Darai E, et al. Ultrasonography compared with magnetic resonance imaging for the diagnosis of adenomyosis: correlation with histopathology. Hum Reprod. 2001;16(11):2427–33.

14. Exacoustos C, Brienza L, Di Giovanni A, et al. Adenomyosis: three-dimensional sonographic findings of the junctional zone and correlation with histology. Ultrasound Obstet Gynecol. 2011;37:471–9.
15. Chiang CH, Chang MY, Hsu JJ, et al. Tumor vascular pattern and blood flow impedance in the differential diagnosis of leiomyoma and adenomyosis by color Doppler sonography. J Assist Reprod Genet. 1999;16(5):268–75.
16. Reid S, Condous G. Transvaginal sonographic sliding sign: accurate prediction of pouch f Douglas obliteration. Ultrasound Obstet Gynecol. 2013;41:605–7.
17. Groszmann YS, Benacerraf BR. Complete evaluation of anatomy and morphology of the infertile patient in a single visit; the modern infertility pelvic ultrasound examination. Fertil Steril. 2016;105:1381–93.
18. Takeuchi H, Kitade M, Kikuchi I, et al. Diagnosis, laparoscopic management, and histopathologic findings of juvenile cystic adenomyoma: a review of nine cases. Fertil Steril. 2010;94:862–8.
19. Kriplani A, Mahey R, Agarwal N, et al. Laparoscopic management of juvenile cystic adenomyoma: four cases. J Minim Invasive Gynecol. 2011;18:343–8.
20. Nabeshima H, Murakami T, Nishimoto M, et al. Successful total laparoscopic cystic adenomyomectomy after unsuccessful open surgery using transtrocar ultrasonographic guiding. J Minim Invasive Gynecol. 2008;15:227–30.
21. Puente JM, Fabris A, Patel J, et al. Adenomyosis in infertile women prevalence and the role of 3D ultrasound as a marker of severity of the disease. Reprod Biol Endocrinol. 2016;14:60.
22. Rasmussen CK, Hansen ES, Dueholm M. Inter-rater agreement in the diagnosis of Adenomyosis by 2 and 3-dimensional Transvaginal ultrasonography. J Ultrasound Med. 2019;38:657–65.
23. Liu X, Ding D, Ren Y, et al. Transvaginal Elastosonography as an imaging technique for diagnosing Adenomyosis. Reprod Sci. 2018;25(4):498–514.
24. Acar S, Millar E, Mitkova M, et al. Value of ultrasound shear wave elastography in the diagnosis of adenomyosis. Ultrasound. 2016;24(4):205–13.
25. Zhang M, Wasnik AP, Masch WR, et al. Transvaginal ultrasound shear wave Elastography for the evaluation of benign uterine pathologies: A prospective pilot study. J Ultrasound Med. 2019;38(1):149–55.
26. Lazzeri L, Morosetti G, Centini G, et al. A sonographic classification of adenomyosis: interobserver reproducibility in the evaluation of type and degree of the myometrial involvement. Fertil Steril. 2018;110(6):1154–1161.e3.
27. Eisenberg, VH, Arbib N, Schiff E, et al. Sonographic Signs of Adenomyosis Are Prevalent in Women Undergoing Surgery for Endometriosis and May Suggest a Higher Risk of Infertility. BioMed Research International, 2017. http://doi.org/10.1155/2017/8967803.
28. Van den Bosch T, de BRUIJN AM, A de LEEUW R, et al. A sonographic classification and reporting system for diagnosing adenomyosis. Ultrasound Obst Gyn. 2018;22(5):764.
29. Van den Bosch T, Dueholm M, Leone FP, et al. Terms, definitions and measurements to describe sonographic features of myometrium and uterine masses: a consensus opinion from the morphological uterus Sonographic assessment (MUSA)group. Ultrasound Obstet Gynecol. 2015;46(3):284–98.