ULTRASOUND OF THE NON-PREGNANT UTERUS

11

INTRODUCTION

Ultrasound is the most optimal imaging modality for the evaluation of the uterus and should be used first when the patient's symptoms suggest the presence of uterine or other surrounding organ abnormalities. The approach to imaging the uterus by ultrasound can be accomplished by the transabdominal or the transvaginal route and is typically dictated by the type of uterine pathology being evaluated. With the exception of large uterine masses, such as uterine leiomyomas, which extend the uterus outside of the pelvis, the transvaginal approach, with its higher resolution and closer proximity to pelvic organs, is preferred, as it enhances the sonographic depiction of normal and abnormal uterine anatomy. Furthermore, the transvaginal transducer allows for direct contact with pelvic tissue and thus can elicit pain or discomfort during the ultrasound examination and thus correlate the patient's symptoms with the sonographic findings. When the transvaginal approach is not feasible, the transrectal or the translabial approach can be used. This chapter discusses and illustrates the sonographic features of the normal non-pregnant uterus and the most common uterine and endometrial malformations.

PREPARATION FOR THE EXAMINATION

Given that the majority of the ultrasound examinations to assess the uterus can be performed with the transvaginal approach, it is recommended that the patient present with an empty bladder. The patient is best placed in a dorsal lithotomy position, with the legs flexed and the perineum at the edge of table, which allows for manipulation of the transvaginal transducer. The transvaginal transducer is best introduced under real-time imaging, and the presence of a chaperone should be considered in accordance with local policies. When a transabdominal ultrasound is performed, the patient's bladder should be distended adequately to displace small bowel from the field of view. A written request for the ultrasound examination should be available and should provide sufficient clinical information to allow for the appropriate performance and interpretation of the examination (1). Refer to chapter 13 for more details on the technical aspects of the transvaginal ultrasound examination. Indications for the examination of the pelvis by ultrasound are listed in **Table 11.1**.

Table 11.1	Indication of Pelvic Sonography Include, but are not Limited to the Following: [Modified with permission from the American Institute of Ultrasound in Medicine (1)]

- Pelvic pain
- Dysmenorrhea (painful menses)
- Amenorrhea (absence of menses)
- Menorrhagia (excessive menstrual bleeding)
- Metrorrhagia (irregular uterine bleeding)
- Menometrorrhagia (excessive irregular uterine bleeding)
- Follow-up of a previously detected abnormality
- Evaluation, monitoring, and/or treatment of infertility patients
- Delayed menses, precocious puberty, or vaginal bleeding in a prepubertal child
- Postmenopausal bleeding
- Abnormal or technically limited manual pelvic examination
- Signs or symptoms of pelvic infection
- Further characterization of a pelvic abnormality noted on another imaging study
- Evaluation of congenital uterine anomalies
- Excessive bleeding, pain, or signs of infection after pelvic surgery, delivery, or abortion
- Localization of an intrauterine contraceptive device
- Screening for malignancy in patients at increased risk
- Urinary incontinence or pelvic organ prolapse
- Guidance for interventional or surgical procedures

SCANNING TECHNIQUES

The sonographic examination of the uterus by the transvaginal approach is typically initiated at the midsagittal plane. This view is obtained by introducing the transvaginal transducer into the upper vaginal fornix while maintaining the reference notch on the transducer at the 12 o'clock position (**Figure 11.1**). In this view, the uterine fundus, uterine isthmus and cervix is seen (**Figure 11.2**) and the uterine length is measured from the fundus to the external os (**Figure 11.2**). The depth (height) of the uterus (anteroposterior dimension) is measured in the same long-axis view from its anterior to posterior walls, perpendicular to the length (**Figure 11.2**). This midsagittal view also allows for assessment and measurement of the endometrium. The endometrium should be analyzed for thickness, focal abnormalities, and the presence of fluid in the endometrial cavity. Measurement of the endometrium should include the anterior and posterior portions while excluding any endometrial fluids (**Figure 11.3**). Accurate evaluation and measurement of the endometrium is important especially in the presence of uterine bleeding. When measuring endometrial thickness on ultrasound, it is critical to ensure that the uterus is in a mid-sagittal plane, the whole endometrial lining is seen from the fundal region to the endocervix, the thickest portion is measured and the image is clear and magnified (**Figure 11.3**). Rotating the transducer 90 degrees counterclockwise (maintains correct orientation) allows for the display of the transaxial or transverse view of the uterus. The operator should fan the probe in the superior – inferior direction until the widest transverse view of the uterus is displayed (**Figure 11.4**). From this widest transverse view, the maximum width of the uterus is measured (**Figure 11.4**).

Figure 11.1: Initial step in the performance of the transvaginal ultrasound examination. Note that the transvaginal transducer is introduced into the vaginal canal with the transducer marker at the 12 o'clock position. A mannequin is used for demonstration.

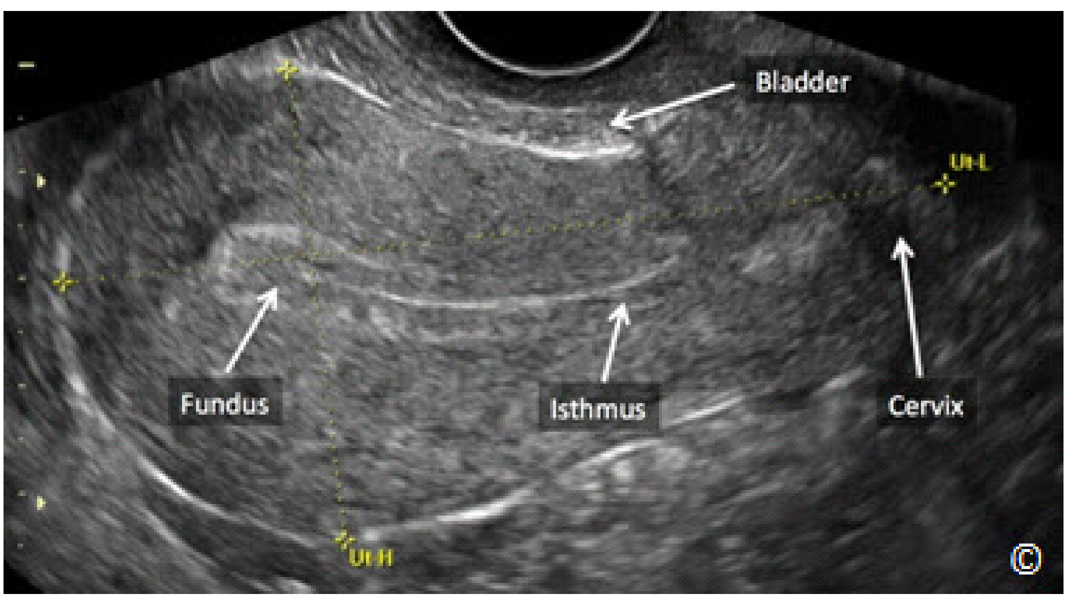


Figure 11.2: Midsagittal plane of the uterus showing the uterine fundus, isthmus, cervix and a collapsed bladder anteriorly (all labeled). In this plane uterine length (Ut-L) and height (Ut-H) are measured.

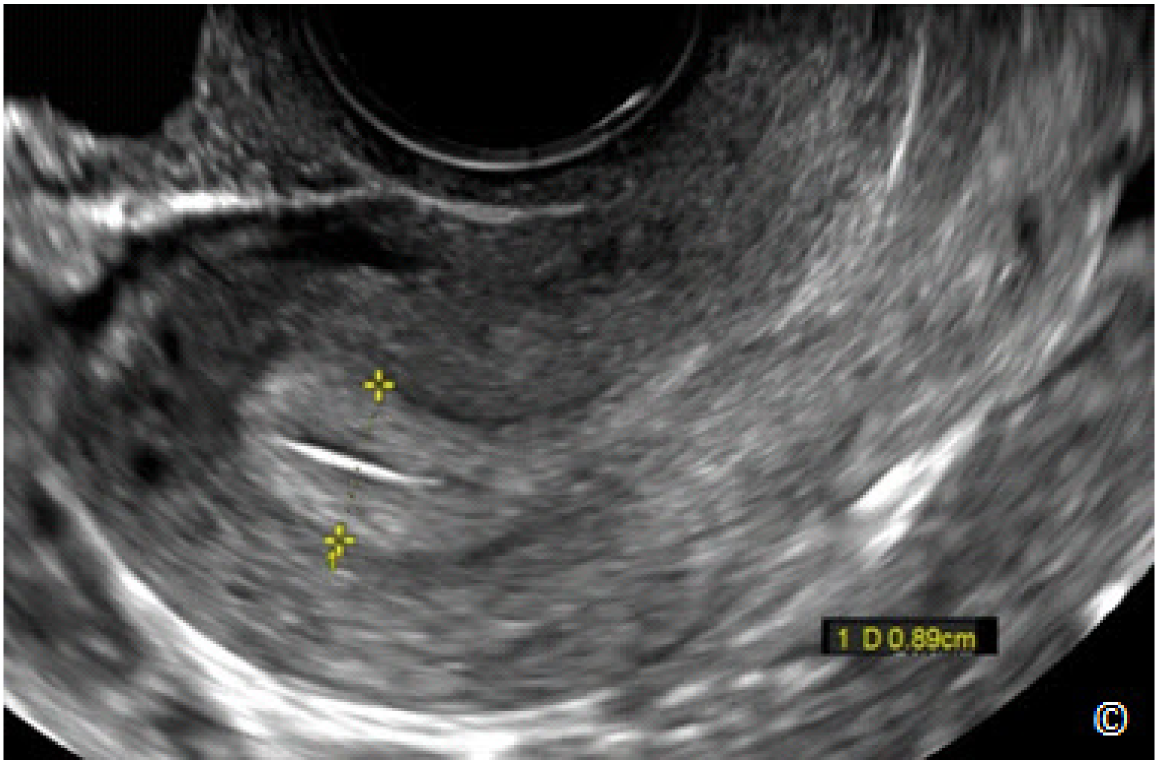


Figure 11.3: Endometrial thickness measurement. Note that the endometrial thickness is measured at its thickest portion and in a midsagittal plane of the uterus. See text for details.

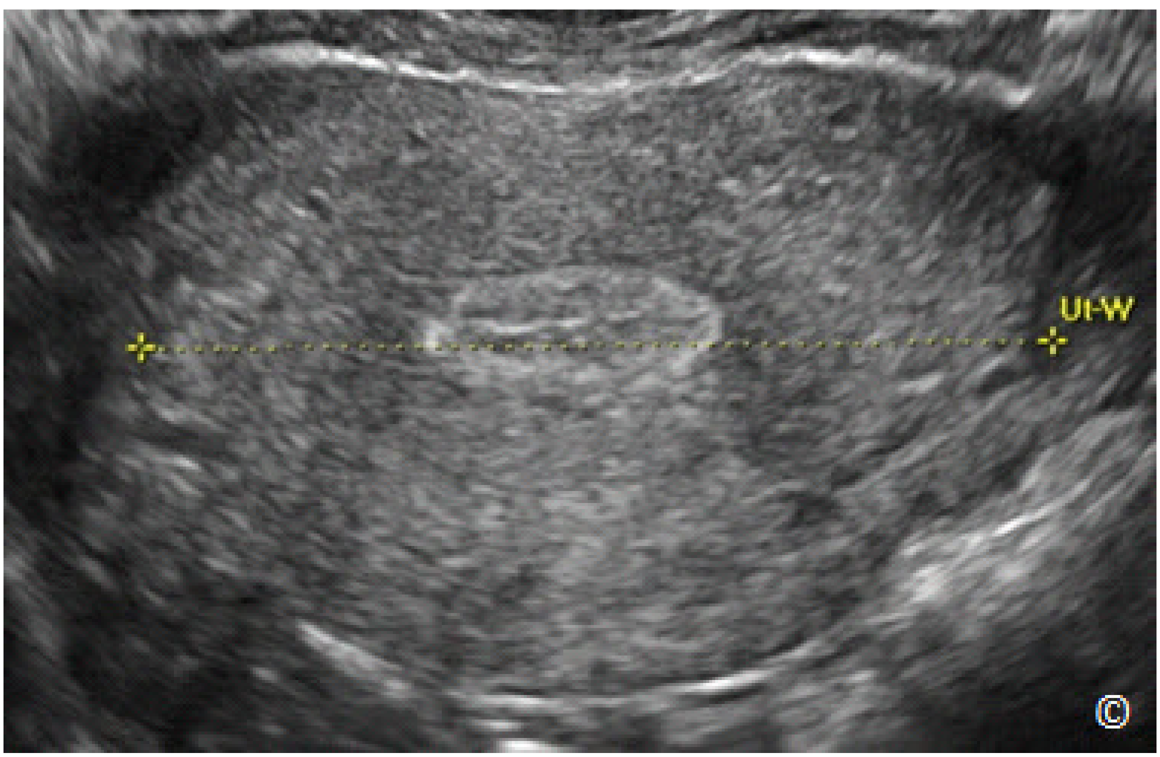


Figure 11.4: Transverse plane of the uterus at its widest dimensions. In this plane uterine width (Ut-W) is measured.

During each ultrasound examination, the uterus should be evaluated for its dimensions (including the endometrium), shape and orientation. The presence of abnormalities involving the cervix, endometrium and myometrium should be evaluated and reported. Adjunct imaging modalities such as color and pulsed Doppler can occasionally help in the presence of abnormal findings. Applying gentle pressure on the transducer while using the other hand on the patient's abdomen to exert counter pressure may help to elicit symptoms in presence of endometritis, endometriosis and pelvic inflammatory disease. This maneuver may also allow assessing for uterine mobility, which is limited in presence of adhesions or scarring. Sonohysterography may be useful for the assessment of the endometrial cavity when an abnormality is suspected (2) (**Figure 11.5**). Sonohysterography (hydrosonography) is performed by inserting a thin, sterile, plastic catheter (insemination catheter or a small feeding tube), connected to a plastic syringe containing sterile saline, into the uterine cavity through the cervical canal (**Figure 11.6**). The author recommends performing the procedure during the proliferative phase of the menstrual cycle to avoid the risk of a pregnant uterus and to ensure a thin endometrium. Other recommendations for sonohysterography to consider include wiping the external cervical os with an aseptic solution before inserting the catheter to minimize the risk of infection and flushing the catheter with saline before insertion to avoid injecting air into the endometrial cavity, which may obscure visualization. The catheter can be inserted easily through the internal cervical os in most women but when cervical stenosis is encountered, the use of a tenaculum to straighten the cervix and a small uterine sound may help in widening the endocervical canal. Side effects of sonohysterography are rare and include around a 1% risk for endometritis and a 1-5 % risk for significant cramping or pain (3). Taking Ibuprofen orally, 1 hour before the procedure, may help to minimize uterine cramping.

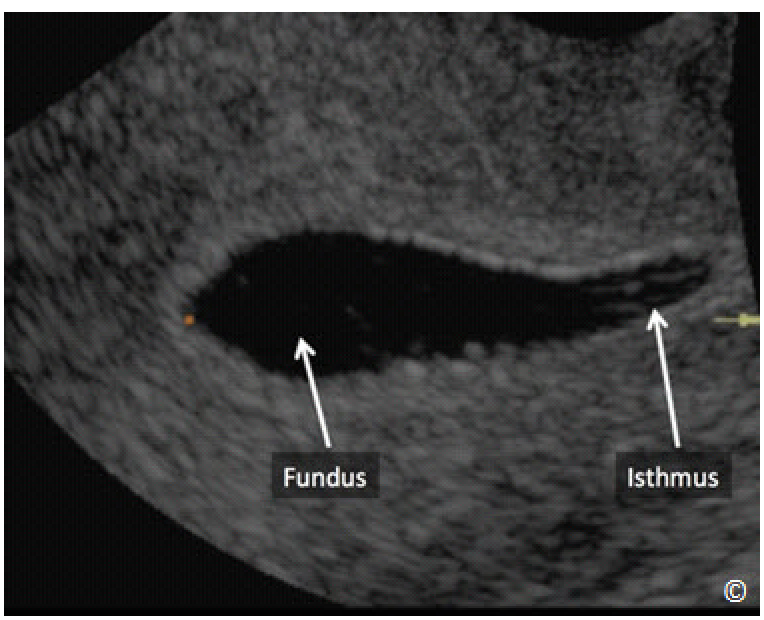


Figure 11.5: Sonohysterography of a normal endometrial cavity showing the fundus and isthmus (labeled).

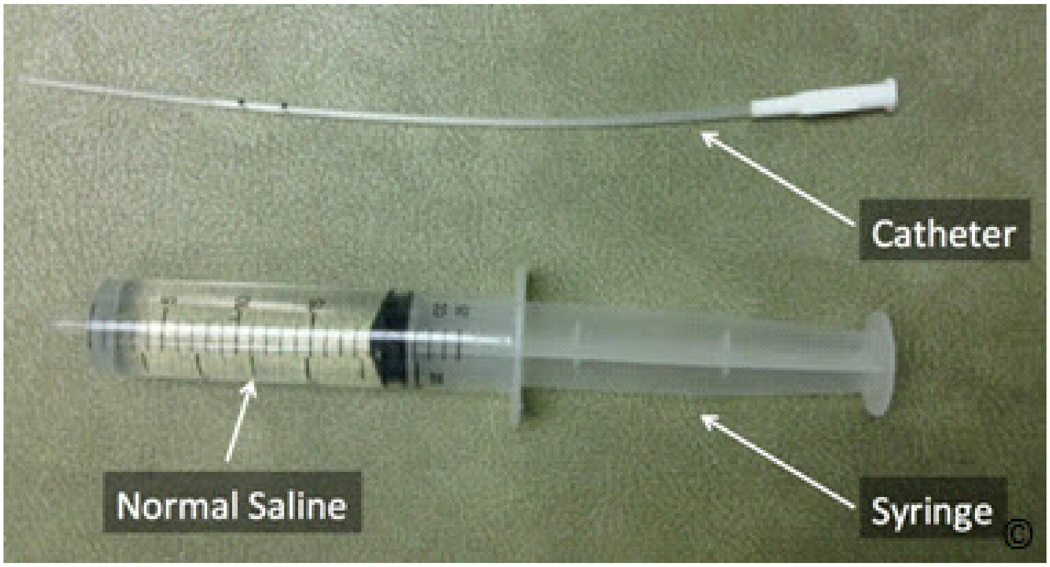


Figure 11.6: Supplies needed for sonohysterography include a syringe filled with sterile normal saline and a thin sterile plastic catheter (labeled). See text for details.

The technical aspect of obtaining the mid-coronal plane of the uterus on three-dimensional sonography will be discussed later in this chapter in the section on congenital mullerian malformations.

SONOGRAPHIC FEATURES OF THE NORMAL UTERUS

The uterus is primarily a muscular organ located in the true pelvis between the urinary bladder anteriorly and the rectosigmoid colon posteriorly. The space between the uterus and the rectosigmoid is the posterior cul-de-sac; the most dependent area in the peritoneal cavity where peritoneal fluid tends to accumulate. In the reproductive years, the endometrium is under the influence of sexual hormones and undergoes anatomic changes during the woman's menstrual cycle.

As described in the section on scanning techniques, the uterus is first imaged in its long axis on the midsagittal plane, which is obtained by visualizing the long axis of the echogenic endometrium. The midsagittal plane allows for the visualization of the uterine fundus, a significant section of the myometrium, the endometrium in sagittal section, the cervix in sagittal section, the cul-de-sac, the rectosigmoid and the bladder (**Figure 11.7**). Measuring the length, depth (height) and width of the uterus, as described in the prior section, should be part of the pelvic ultrasound examination. The length of a normal nulliparous uterus is 6 - 8.5 cm and in multiparous women it is 8 - 10.5 cm (4). The depth (height) of the normal uterus in nulliparous women is 2 – 4 cm and in multiparous women it is 4 – 6 cm (4). The widest transverse plane of the uterus measures 3 – 5 cm in nulliparous and 4 – 6 cm in multiparous women (4).

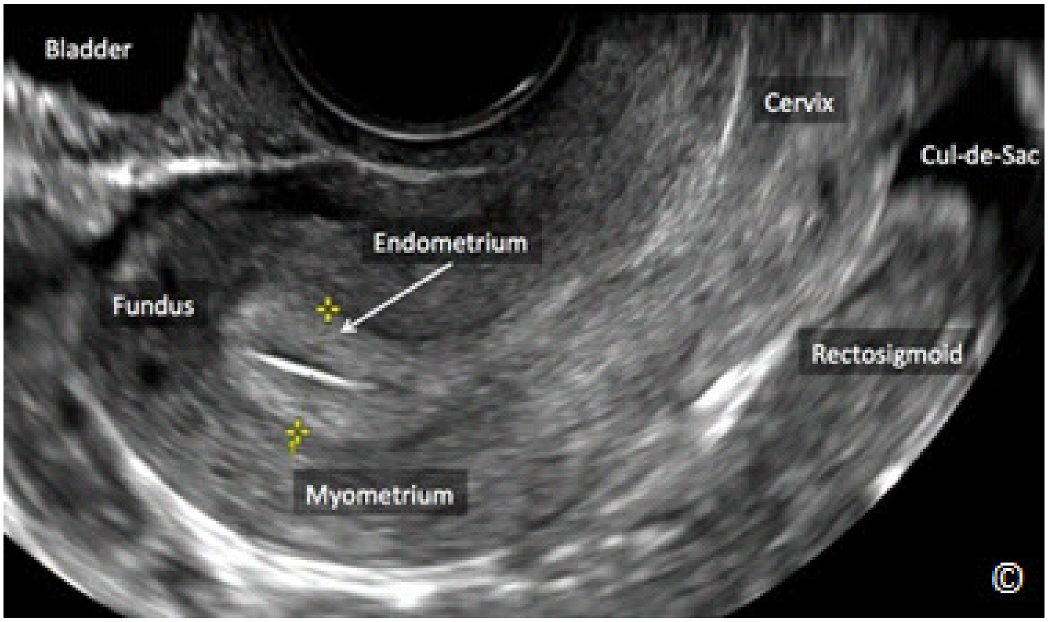


Figure 11.7: Midsagittal plane of the uterus showing the uterine fundus, the myometrium, the endometrium, the cervix, the cul-de-sac, the rectosigmoid and the bladder (all labeled). Note that the myometrium is less echogenic than the endometrium (labeled).

It is important to describe and report the orientation of the uterus as part of the ultrasound examination as this information is helpful if uterine instrumentation is required. The orientation of the uterus is described in the midsagittal plane and in relation to the supine body. Two terms are used to describe the orientation of the uterus in the pelvis; flexion and version. Flexion is the bending of the uterus on itself and thus the uterus is flexed when there is an angle in the midsagittal plane between the cervix/lower uterine (isthmus) segment and the fundal portion. An anteroflexed uterus is a uterus with an acute or obtuse angle (< 180 degrees) between the cervix/lower uterine (isthmus) segment and the fundus with the fundal portion close to the bladder (**Figure 11.8**). A retroflexed uterus is a uterus with a reflex angle (> 180 degrees) between the cervix/lower uterine (isthmus) segment and the fundus with the fundal portion close to the rectosigmoid (**Figure 11.9**). If there is no angulation between the cervix/lower segment (isthmus) and the uterine fundus, the uterus is described in terms of version. Version thus describes displacement of the entire uterus forwards or backwards. An anteverted uterus is a uterus where the fundal portion is close to the bladder (**Figure 11.10**) and a retroverted uterus is a uterus where the fundal region is close to the rectosigmoid (**Figure 11.11**).

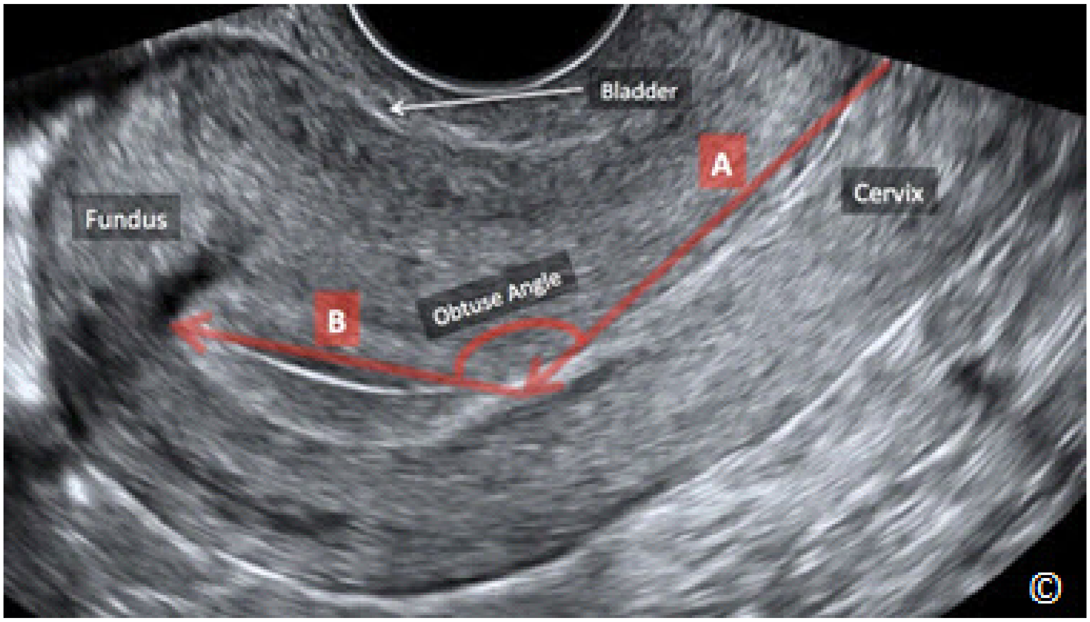


Figure 11.8: Transvaginal ultrasound of an anteroflexed uterus. Note the obtuse angle (< 180^{o}) between the lower uterine segment (isthmus)/ cervix (A) and the fundal portion (B). The uterine fundus is close to the bladder (compressed - labeled).

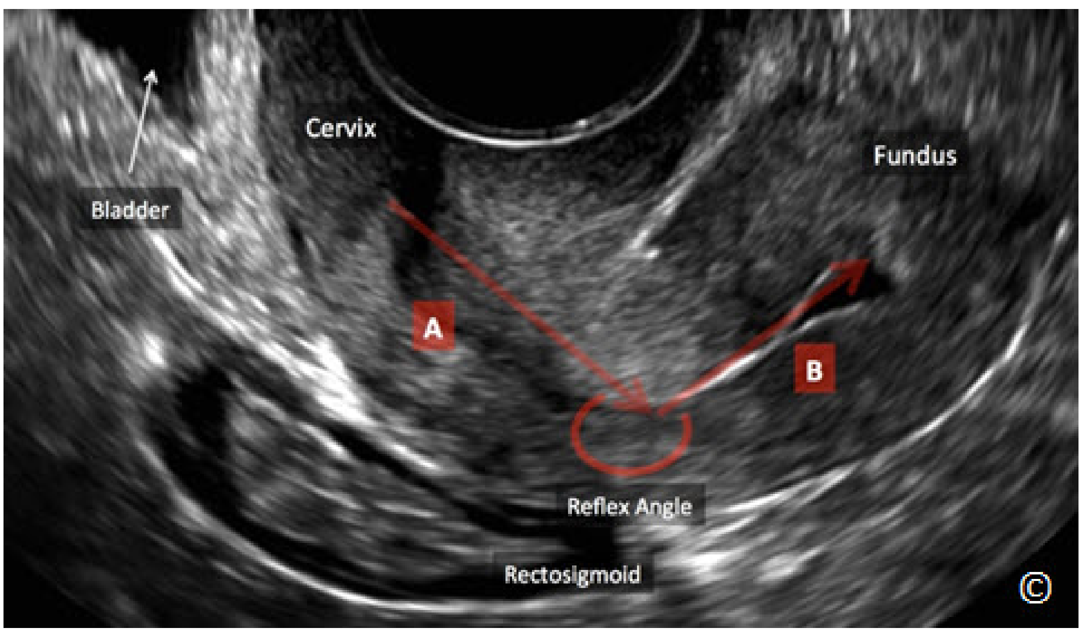


Figure 11.9: Transvaginal ultrasound of a retroflexed uterus. Note the reflex angle (> 180^{o}) between the lower uterine segment (isthmus) / cervix (A) and the fundal portion (B). The uterine fundus is close to the rectosigmoid (labeled). Note location of bladder (labeled).

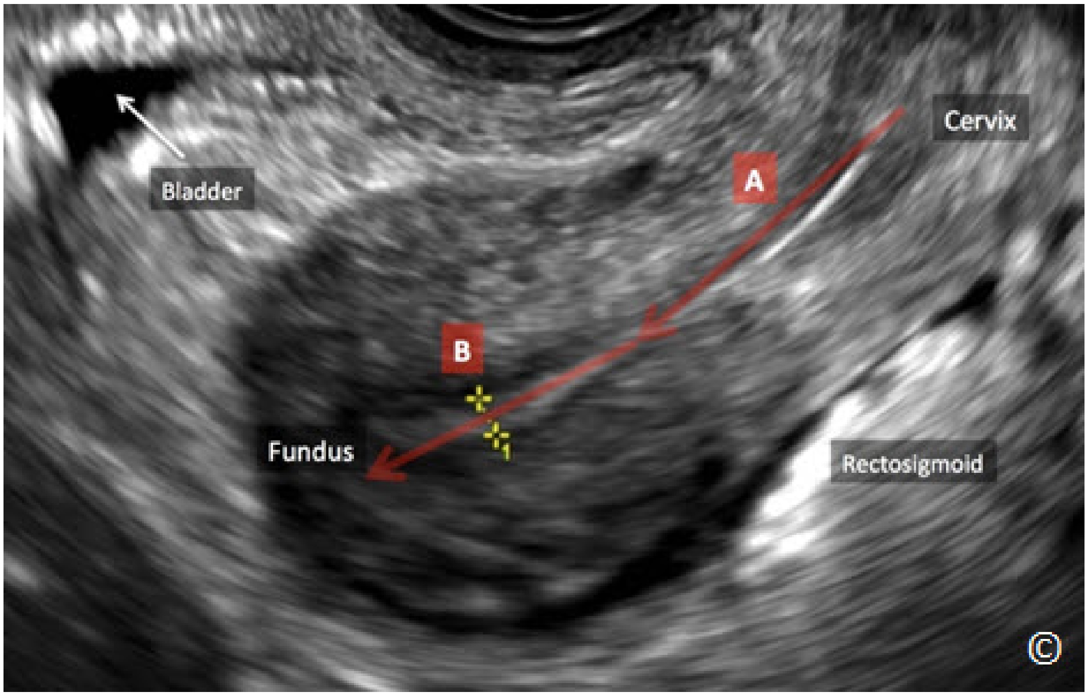


Figure 11.10: Transvaginal ultrasound of an anteverted uterus. Note the absence of angulation between the lower uterine segment (isthmus)/ cervix (A) and the fundal portion (B). The fundal portion is close to the bladder (labeled). Rectosigmoid is labeled.

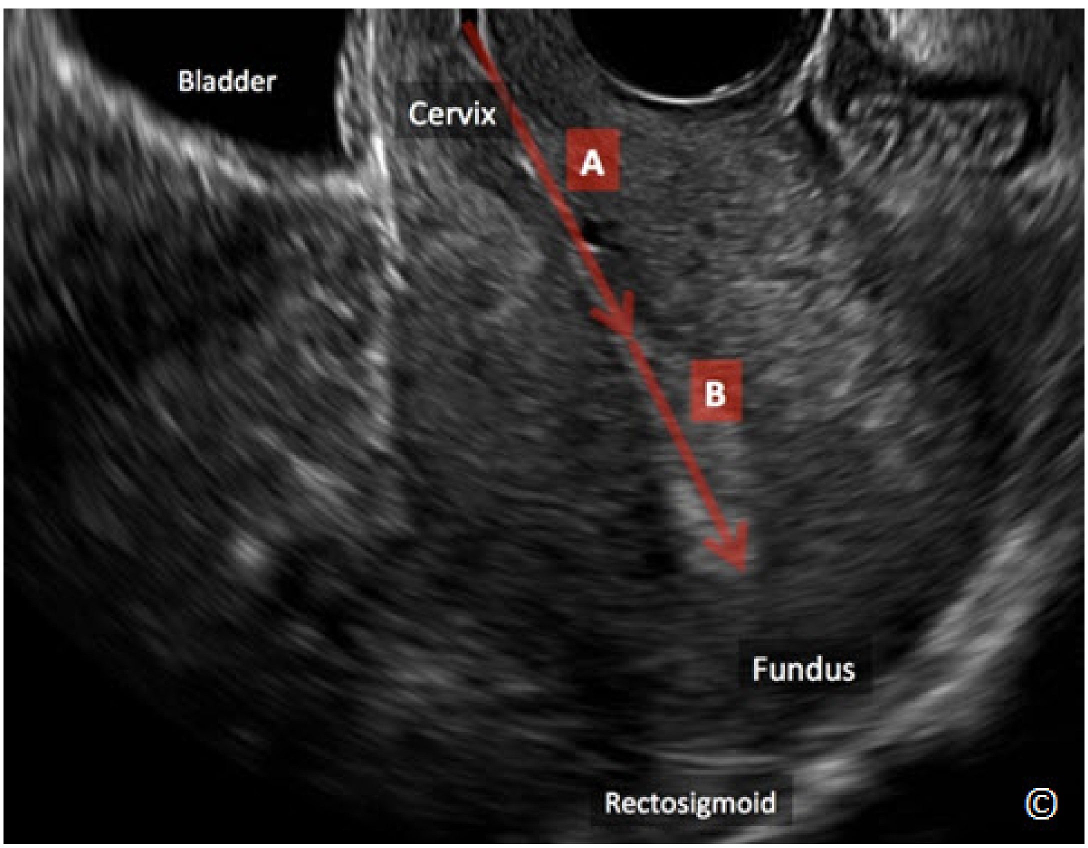


Figure 11.11: Transvaginal ultrasound of a retroverted uterus. Note the absence of angulation between the lower uterine segment (isthmus)/ cervix (A) and the fundal portion (B). The fundal portion is close to the rectosigmoid (labeled). Note the location of the bladder (labeled).

The myometrium is made of a homogeneous layer of smooth muscle and blood vessels. Sonographically the normal myometrium is less echogenic than the endometrium (**Figure 11.7**). The myometrium can be divided into three layers; the inner or junctional layer, which abuts the endometrium, is thin and hypoechoic, the middle layer is thick and homogeneous and an outer layer which is thin and hypoechoic (**Figure 11.12**). The arcuate vessels separate the middle from the outer myometrial layers.

The endometrium undergoes significant change during the menstrual cycle (5, 6) and anatomically is divided into the inner functional layer that sloughs during the menstrual cycle and the outer basal layer that abuts the myometrial junctional layer. Sonographically, in the immediate postmenstrual phase, the endometrium appears as a thin echogenic line and typically measures between 3 – 8 mm (Type A) (**Figure 11.13**). Under the influence of increasing estradiol hormone levels secreted by the growing ovarian follicles, endometrial proliferation occurs and endometrial thickening ensues. Sonographically, this is seen as thickening of the lining into the so-called trilaminar layer (Type B) with an anterior and posterior hypoechoic layer separated in the midline by an echogenic central line. During the late proliferative period and near the time of ovulation, endometrial lining is 8 to 12 mm in thickness with an accentuated trilaminar appearance (Type C), (**Figure 11.14**). The post ovulatory endometrial lining, under the influence of progesterone hormone, secreted by the corpus luteum, is characterized by loss of the trilaminar appearance and the development of a uniformly hyperechoic endometrium (Type D), **(Figure 11.15)**.

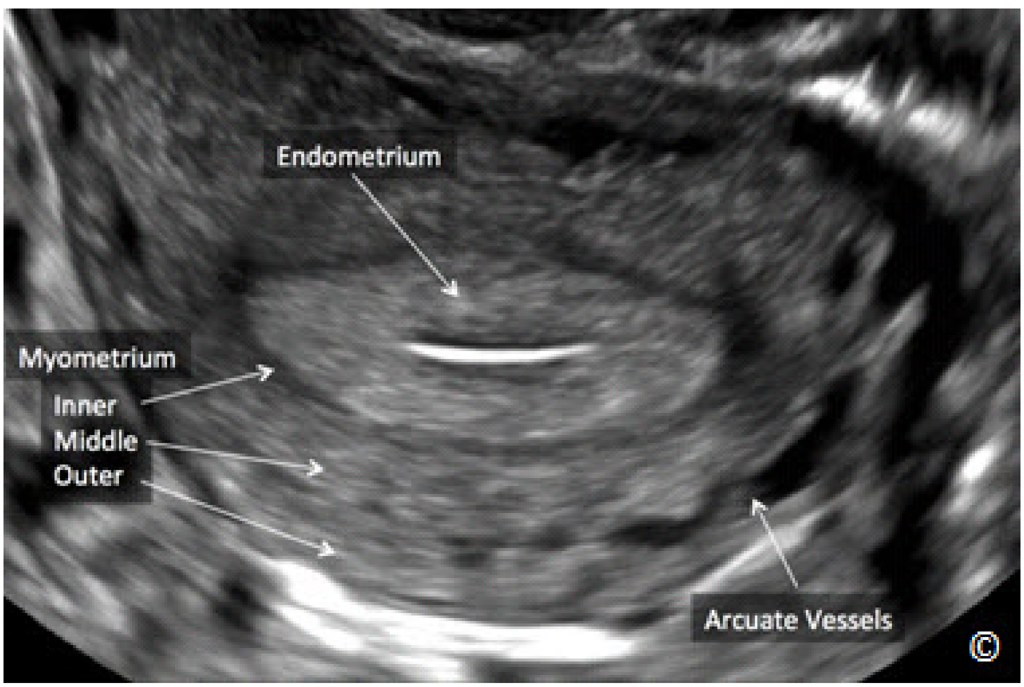


Figure 11.12: Transvaginal ultrasound of a transverse view of the uterus showing the three myometrial layers. Note the inner thin and hypoechoic layer that abuts the endometrium (labeled), the middle layer that is thick and homogeneous and the outer layer that is slightly less echogenic than the middle layer (labeled). Note that the arcuate vessels (labeled) separate the middle from the outer myometrial layers.

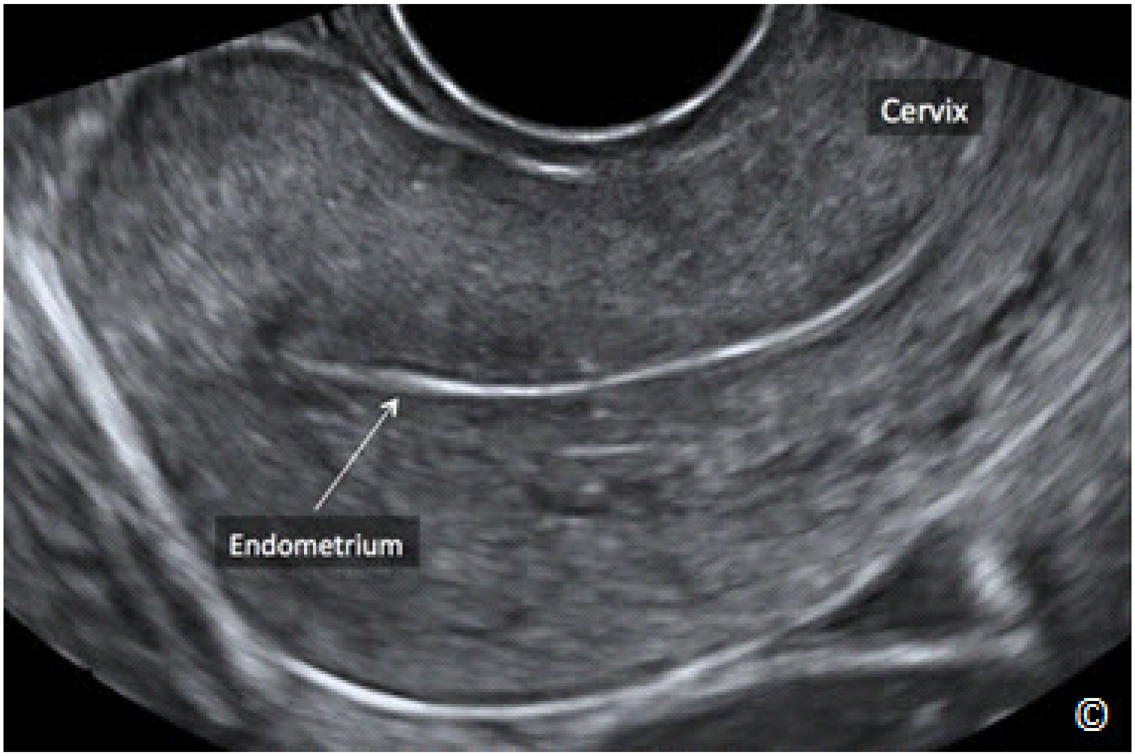


Figure 11.13: Transvaginal ultrasound of a sagittal view of the uterus in the immediate postmenstrual phase. Note the thin echogenic endometrium (labeled). Cervix is labeled for image orientation. Image is courtesy of Dr. Bernard Benoit.

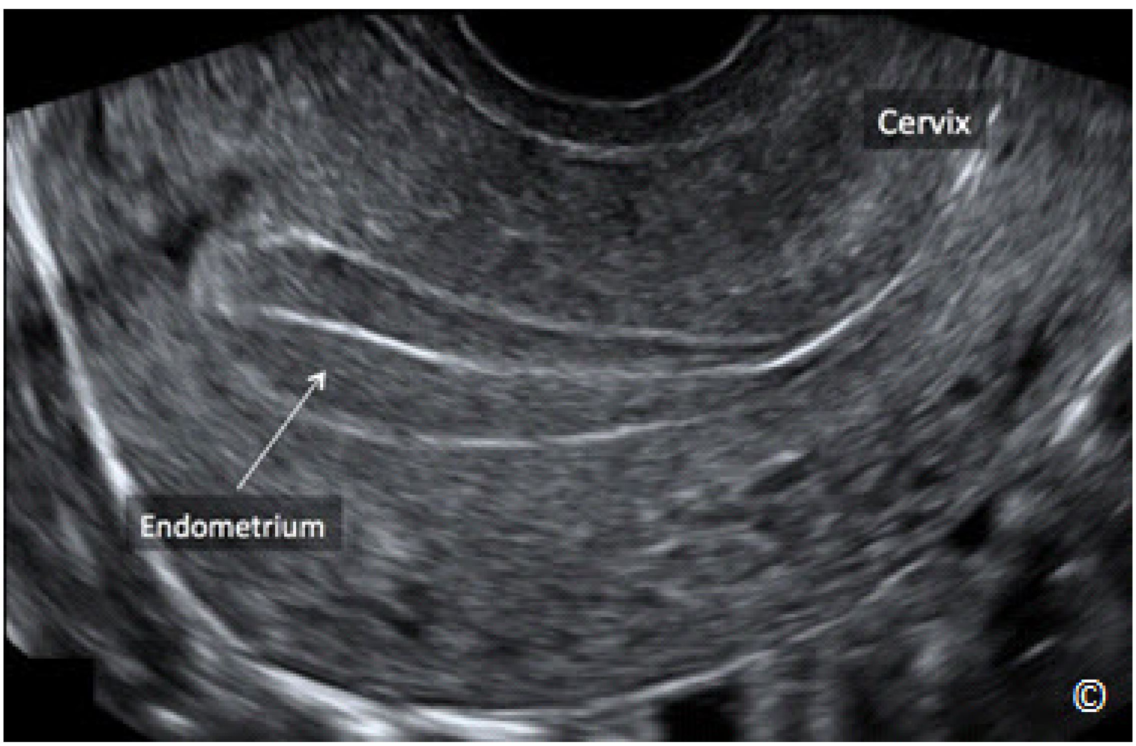


Figure 11.14: Transvaginal ultrasound of a sagittal view of the uterus in the late proliferative, near ovulation phase of the menstrual cycle. Note the accentuated thick trilaminar endometrium (labeled). Cervix is labeled for image orientation. Image is courtesy of Dr. Bernard Benoit.

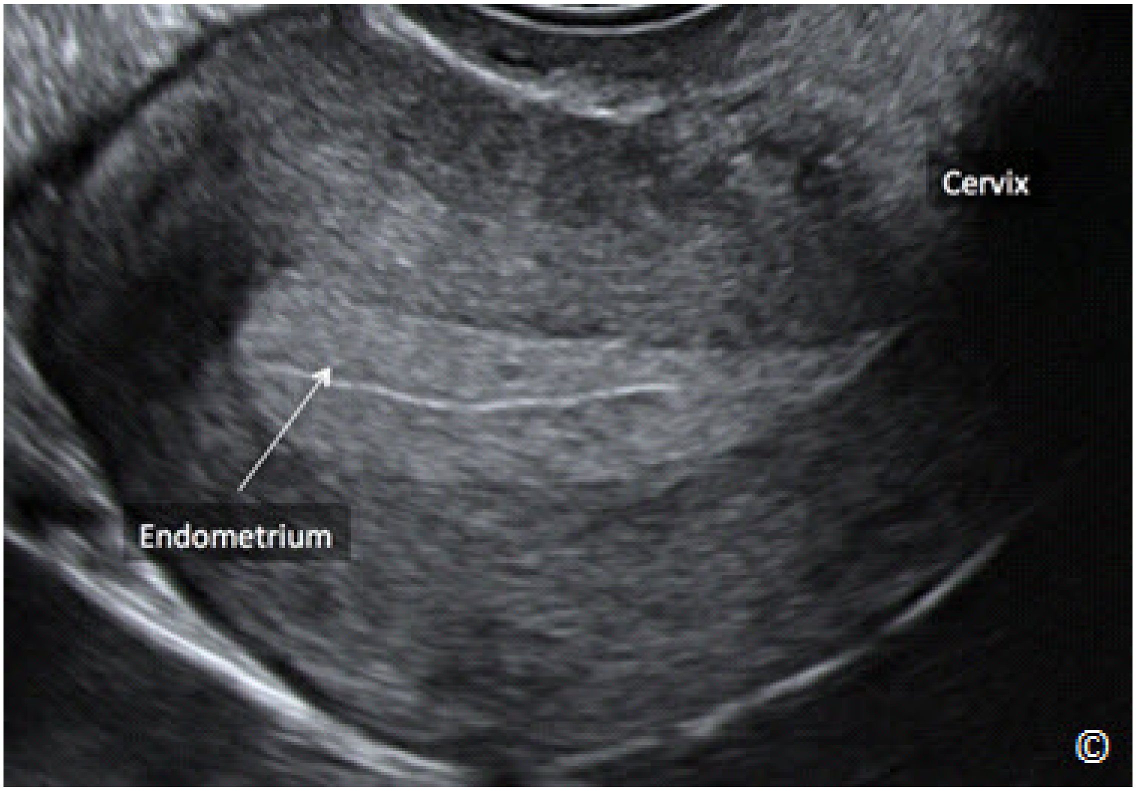


Figure 11.15: Transvaginal ultrasound of a sagittal view of the uterus in the post-ovulatory phase of the menstrual cycle. Note that the endometrium is uniformly hyperechoic with the loss of the trilaminar appearance (labeled). Cervix is labeled for image orientation. Image is courtesy of Dr. Bernard Benoit.

The cervix can be divided into the portio vaginalis or ectocervix, the endocervix and the endocervical canal. It is best imaged using the transvaginal approach. To fully display the cervix, the transvaginal transducer is rotated to the midsagittal position, and is pulled gently backward until the whole cervix comes into view. Applying transducer pressure should be avoided, as it will distort the cervix. Sonographically, the cervical stroma is of the same consistency as the myometrium, and is not affected by hormonal changes (7). Nabothian cysts can be occasionally seen within the cervical stroma (**Figure 11.16**).

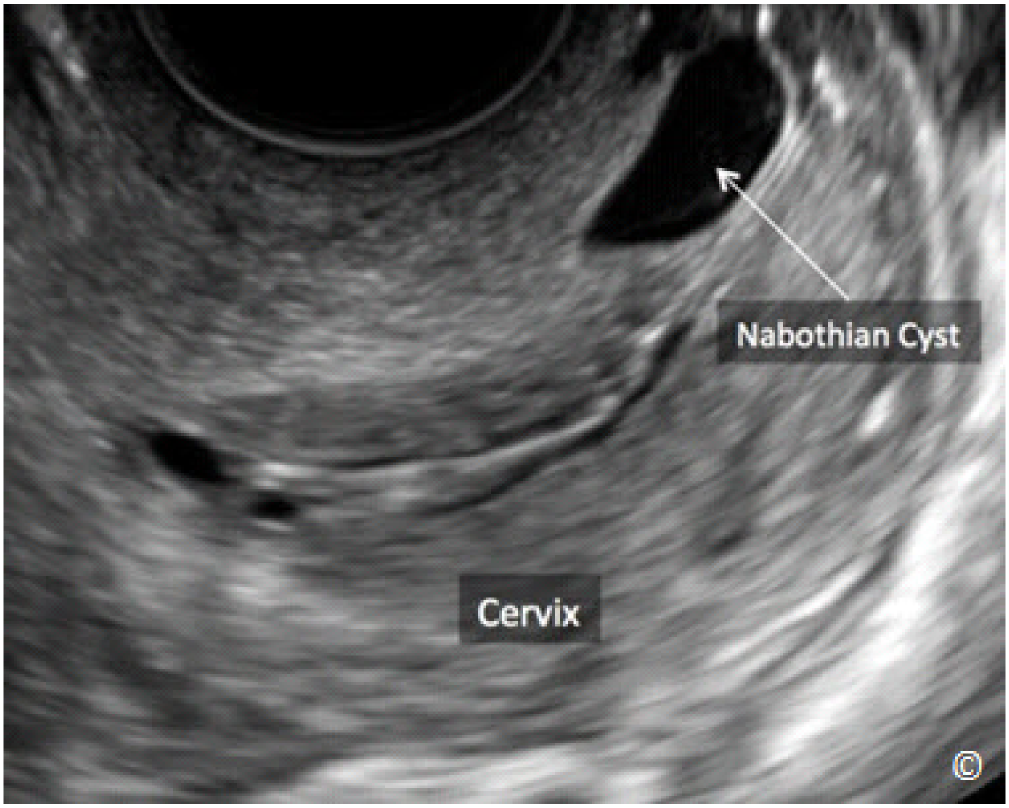


Figure 11.16: Transvaginal ultrasound of the cervix in sagittal view. Note the presence of a Nabothian cyst (labeled), which typically presents as an anechoic cyst within the cervical stroma

ADENOMYOSIS

Adenomyosis is a common condition that predominantly affects women in the late reproductive years. It has been noted to occur in about 30% of the general female population and in up to 70% of hysterectomy specimens depending on the definition of the entity (8). Adenomyosis is defined by the presence of ectopic endometrial glands and stroma within the myometrium, which induces a hypertrophic and hyperplastic reaction in the surrounding myometrial tissue.

Most patients with adenomyosis are asymptomatic. Symptoms related to adenomyosis include dysmenorrhea, dyspareunia, chronic pelvic pain and menometrorrhagia. Adenomyosis presents most commonly as a diffuse disease involving the entire myometrium (**Figure 11.17**). Adenomyosis can also present in a focal area of the uterus, known as adenomyoma (**Figure 11.18**). Adenomyosis is occasionally associated with other uterine pathology such as leiomyoma and endometrial polyps. Clinical diagnosis of adenomyosis is difficult due to its vague presenting symptoms. A homogeneously enlarged (globular) uterus on pelvic examination is suggestive of the diagnosis (**Figure 11-17**).

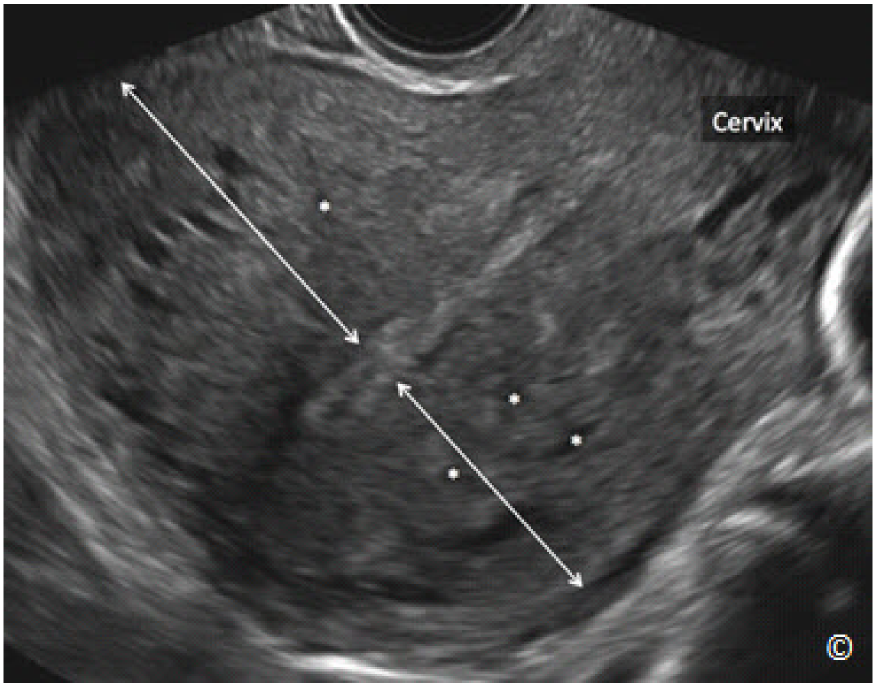


Figure 11.17: Transvaginal ultrasound of the uterus in sagittal view in the presence of diffuse adenomyosis. Note the globular enlargement of the uterus, the asymmetric anterior and posterior wall thickness (arrows) and the presence of multiple anechoic spaces within the myometrium (asterisks). The cervix is labeled for image orientation. See text and **Table 11.2** for more details.

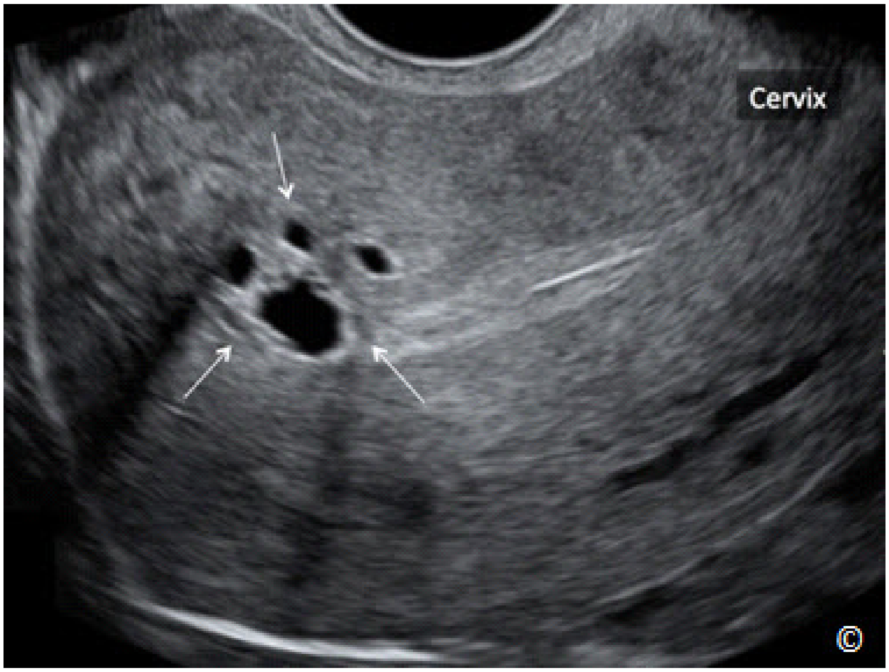


Figure 11.18: Transvaginal ultrasound of the uterus in sagittal view in the presence of focal adenomyosis (arrows). Note the presence of multiple anechoic spaces (arrows) within the myometrium. See text and **Table 11.2** for more details. The cervix is labeled for image orientation. Image is courtesy of Dr. Bernard Benoit.

Ultrasound features of adenomyosis have been described in the literature (9) and are listed in **Table 11.2**. **Figures 11.17** to **11.19** show the common ultrasound features of adenomyosis. The diagnosis of adenomyosis by ultrasound is best performed by the transvaginal approach and its clinical implication is most significant in symptomatic women. On some occasions, differentiating adenomyosis from a leiomyoma may be difficult and color/pulsed Doppler may be helpful in that setting (10, 11).

TABLE 11.2	Ultrasound Findings in Adenomyosis
	- Globular enlargement of the uterus - Anechoic spaces in the myometrium - Asymmetric anterior and posterior uterine wall thickening - Subendometrial echogenic linear striations - Heterogeneous echo texture - Obscure endometrial-myometrial border - Thickening of the transition zone

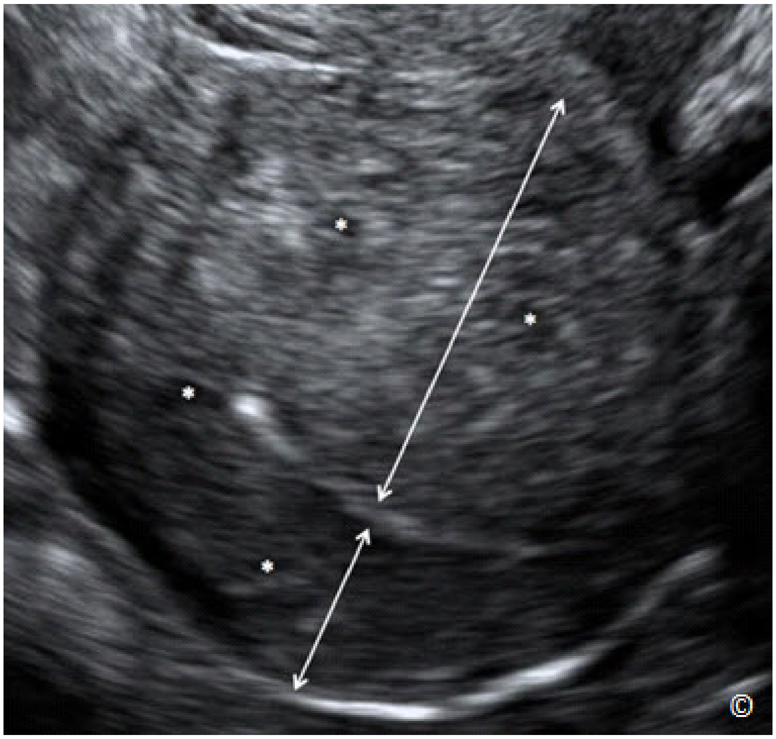


Figure 11.19: Transvaginal ultrasound of the uterus in sagittal view in the presence of diffuse adenomyosis. Note the globular enlargement of the uterus, the asymmetric anterior and posterior wall thickness (arrows), the presence of multiple anechoic spaces within the myometrium (asterisks) and the heterogeneous echo texture. See text and **Table 11.2** for more details.

CONGENITAL UTERINE MALFORMATIONS

The true prevalence of female genital tract malformations is unknown (12), but can be up to 8-10% in women with recurrent pregnancy loss (13). Congenital uterine malformations are associated with an increased risk of infertility, miscarriage, premature birth, fetal loss, fetal malpresentation and cesarean sections (14, 15). Accurate diagnosis of the specific type of a uterine anomaly is of clinical importance as the prognosis and the need for surgical repair is dependent on this distinction. The American Fertility Society's classification (1988) consists of seven basic groups that are based on Mullerian development and its relationship to fertility: (1) agenesis and hypoplasias, (2) unicornuate uteri, (3) didelphys uteri, (4) bicornuate uteri, (5) septate uteri, (6) arcuate uteri and (7) anomalies related to diethylstilbestrol exposure syndrome (16). In this classification, additional findings referring to the vagina, cervix, fallopian tubes, ovaries and urinary system must be addressed separately.

Although transvaginal 2D sonography has been shown to be a good screening tool for the detection of uterine anomalies with a sensitivity as high as 90 % (17, 18), its ability is limited however to distinguish between different anomaly types with certainty (19). The development of three-dimensional (3D) ultrasound has permitted scanning of the uterus in coronal planes, which allows for accurate depiction of the endometrial and serosal fundus in such planes and thus allowed for accurate distinction between various types of uterine malformations (**Figure 11.20**). When the uterus is viewed in the midcoronal plane on 3D ultrasound, indentation in the serosal and endometrial fundus can be seen and measurement of the distance between the mid-fundus and a line connecting the two internal tubal ostia can be obtained (**Figure 11.21**). **Table 11.3** lists the criteria used by the authors for the classification of congenital uterine malformations by 3D ultrasound.

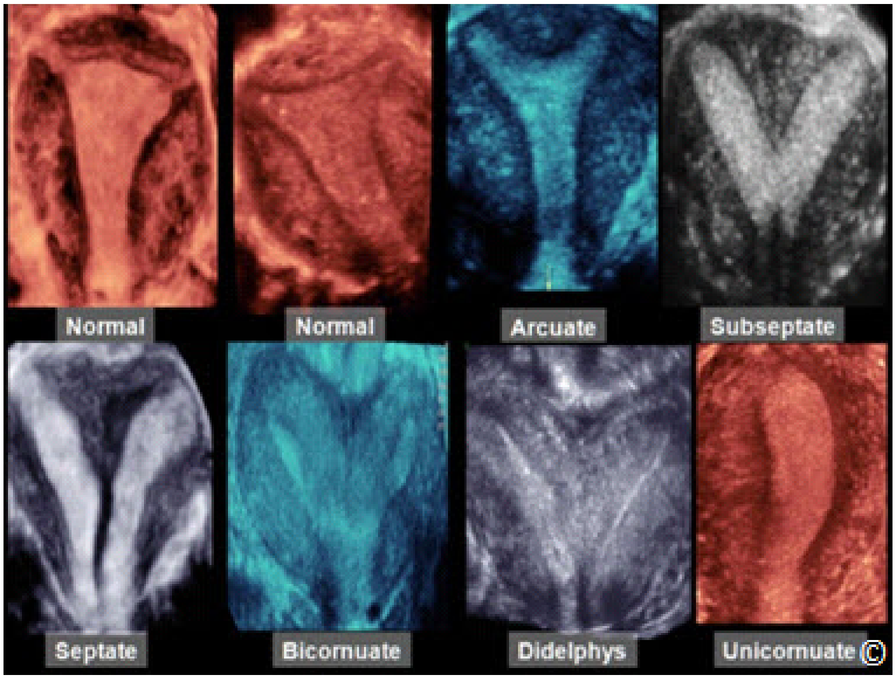


Figure 11.20: Midcoronal planes of uteri obtained from 3-D ultrasound volumes in normal and abnormal uterine abnormalities. Note the clear depiction of the serosal and endometrial fundi and lower-uterine segments, which allow for differentiation of various mullerian anomalies. See **Table 11.3** for details. Modified with permission from the American Institute of Ultrasound in Medicine (18).

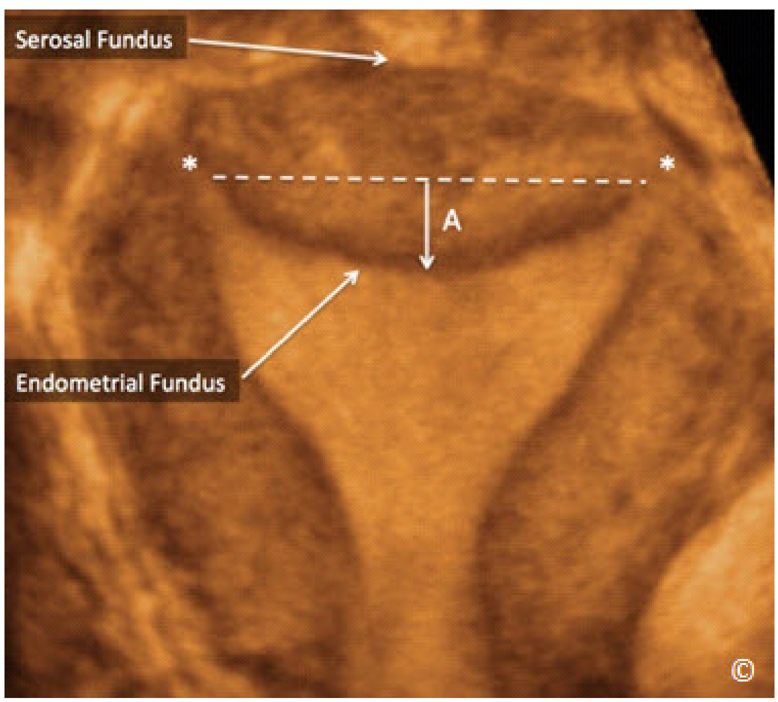


Figure 11.21: Midcoronal plane of the uterus obtained from a 3D ultrasound volume showing the serosal fundus (labeled), the endometrial fundus (labeled) and the location of the two internal tubal ostia (asterisks). Note that the indentation of the endometrial fundus (A) is measured as the distance from a line connecting the two tubal ostia (dashed line) to the mid-endometrial fundus (arrow-A). See **Table 11.3** for details. Image is courtesy of Dr. Bernard Benoit.

TABLE 11.3 **Classification of Mullerian Malformations by 3D Ultrasound (Modified with Permission from Reference 20)**

Uterine Morphology	Endometrial Fundus	Serosal Fundus
Normal	Straight or Convex	Uniformly convex or with <10 mm indentation
Arcuate	Concave fundal indentation with central point of indentation at obtuse angel (>90°) – or indentation < 10 mm	Uniformly convex or with indentation <10 mm
Subseptate	Presence of septum, which does not extend to cervix, with central point of septum at an acute angle (<90°) – indentation > 10 mm	Uniformly convex or with indentation <10 mm
Septate	Presence of uterine septum that completely divides cavity from fundus to cervix	Uniformly convex or with indentation <10 mm
Bicornuate	Two well-formed uterine cornua – two cavities commonly communicate in isthmus / cervical region	Fundal indentation >10 mm dividing the two cornua
Didelphys	Two well-formed uterine cornua – two cavities that are wide apart and do not communicate	Fundal indentation >10 mm dividing the two cornua
Unicornuate with or without rudimentary horn	Single well-formed uterine cavity with a single interstitial portion of fallopian tube and concave fundal contour	Fundal indention >10 mm dividing the 2 cornua if rudimentary horn present

We have described an easy technique for the retrieval of the midcoronal plane from a 3D uterine volume (21). This standardized technique, termed, the Z-technique, is easy to learn, reduces operator dependency and enhances the diagnostic accuracy of 3D ultrasound in the detection of mullerian anomalies. **Table 11.4** and corresponding **Figures 11.22** to **11.26** details the sequence of steps for the display of the midcoronal plane of the uterus from a 3D volume using the Z-technique.

TABLE 11.4	The Z-Technique: Steps for the Retrieval of the Midcoronal Plane in a 3D Volume of the Uterus [Modified with Permission from the American Institute of Ultrasound in Medicine (21)].

Step 1. Place the reference/rotational point in the midlevel of the endometrial lining in the sagittal plane (**Figure 11.22**)

Step 2. Use the Z rotation to align the long axis of the endometrial lining along the horizontal axis in the sagittal plane of the uterus (**Figure 11.23**)

Step 3. Place the reference/rotational point in the midlevel of the endometrial lining in the transverse plane (**Figure 11.24**)

Step 4. Use the Z rotation to align the endometrial lining with the horizontal axis in the transverse plane of the uterus (**Figure 11.25**)

Step 5. After step 4, the midcoronal plane of the uterus will be displayed in plane C (**Figure 11.25**); apply Z rotation on plane C to display the midcoronal plane in the traditional orientation (**Figure 11.26**).

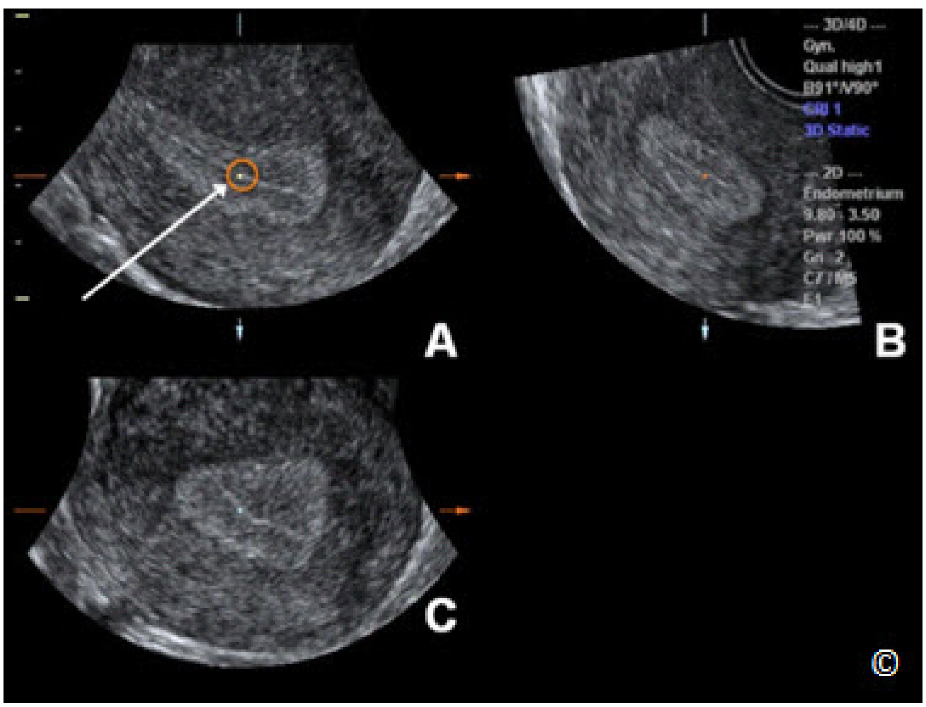


Figure 11.22: 3D volume of the uterus in multiplanar display. Plane A represents the reference plane (sagittal in this case) and B and C represent 2 orthogonal planes. The initial step in the Z-Technique involves placing the reference/rotational point in the midlevel of the endometrial lining in plane A (circle and arrow). Modified with permission from the American Institute of Ultrasound in Medicine (21).

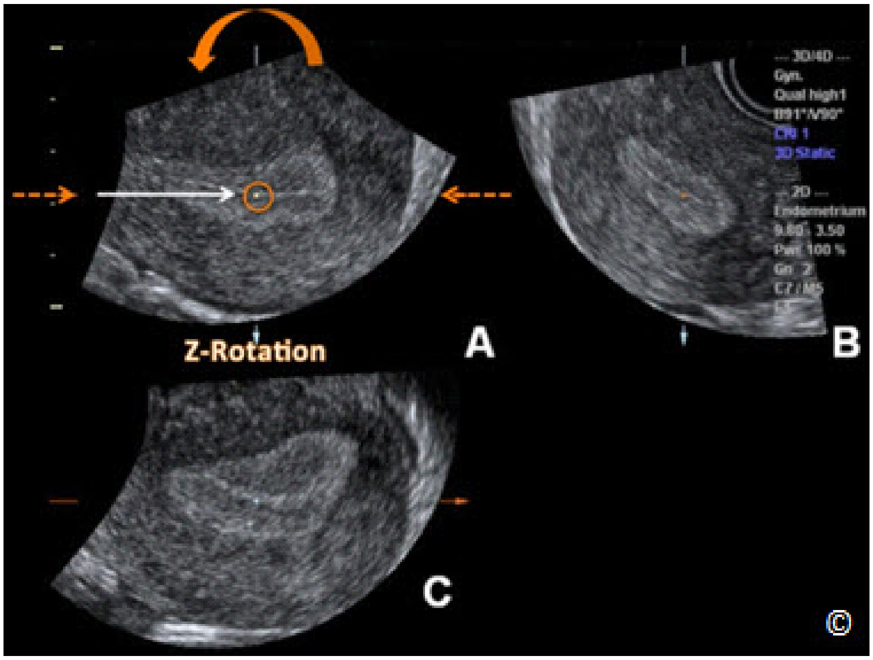


Figure 11.23: 3D volume of the uterus (same as in **Figure 11.22**) in multiplanar display. The second step in the Z-Technique involves aligning the long axis of the endometrial lining in plane A along the horizontal axis (dashed arrows) by rotating plane A along the Z-axis (curved arrow). The white arrow and circle shows the reference/rotational point. Modified with permission from the American Institute of Ultrasound in Medicine (21).

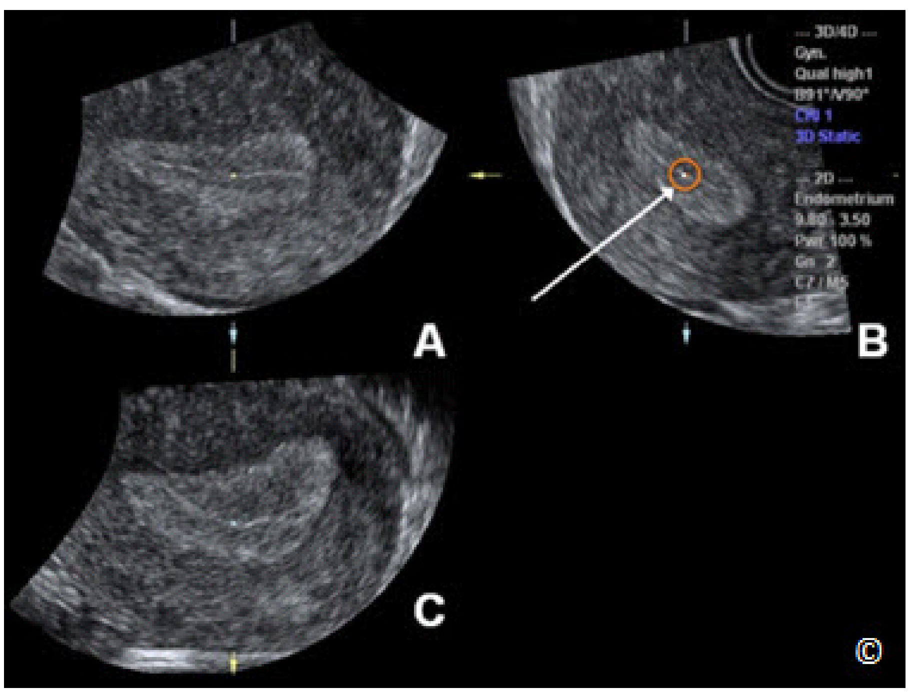


Figure 11.24: 3D volume of the uterus (same as in **Figure 11.22**) in multiplanar display. The third step in the Z-Technique involves placing the reference/rotational point in the midlevel of the endometrial lining in the transverse plane (plane B). The white arrow and circle shows the reference/rotational point in B. Modified with permission from the American Institute of Ultrasound in Medicine (21).

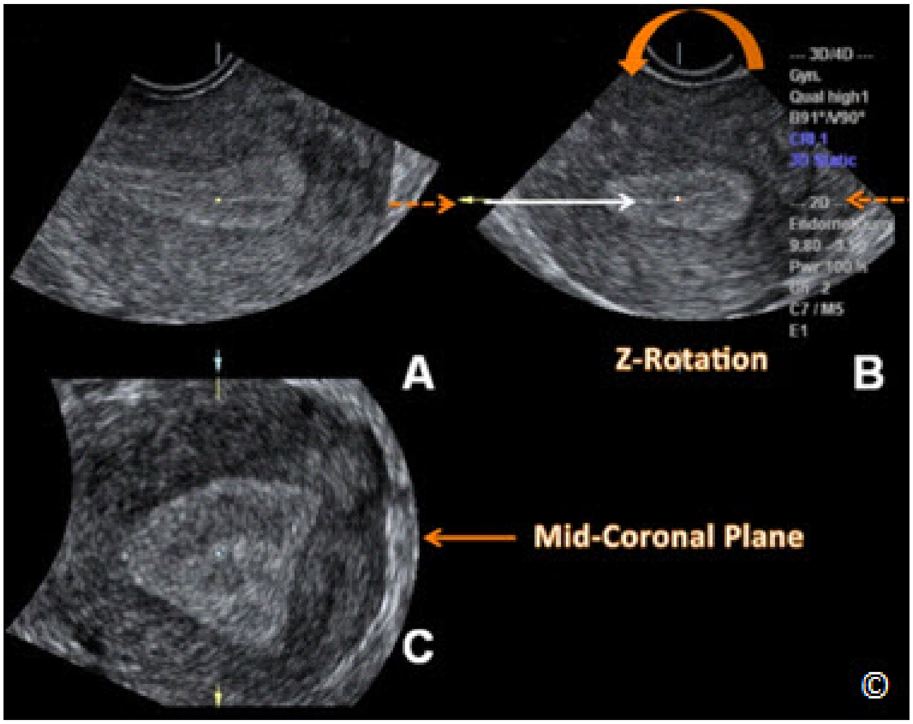


Figure 11.25: 3D volume of the uterus (same as in **Figure 11.22**) in multiplanar display. The fourth step in the Z-Technique involves aligning the long axis of the endometrial lining in plane B along the horizontal axis (dashed arrows) by rotating plane B along the Z-axis (curved arrow). Note that the mid-coronal plane is displayed in plane C. The white arrow shows the reference/rotational point in plane B. Modified with permission from the American Institute of Ultrasound in Medicine (21).

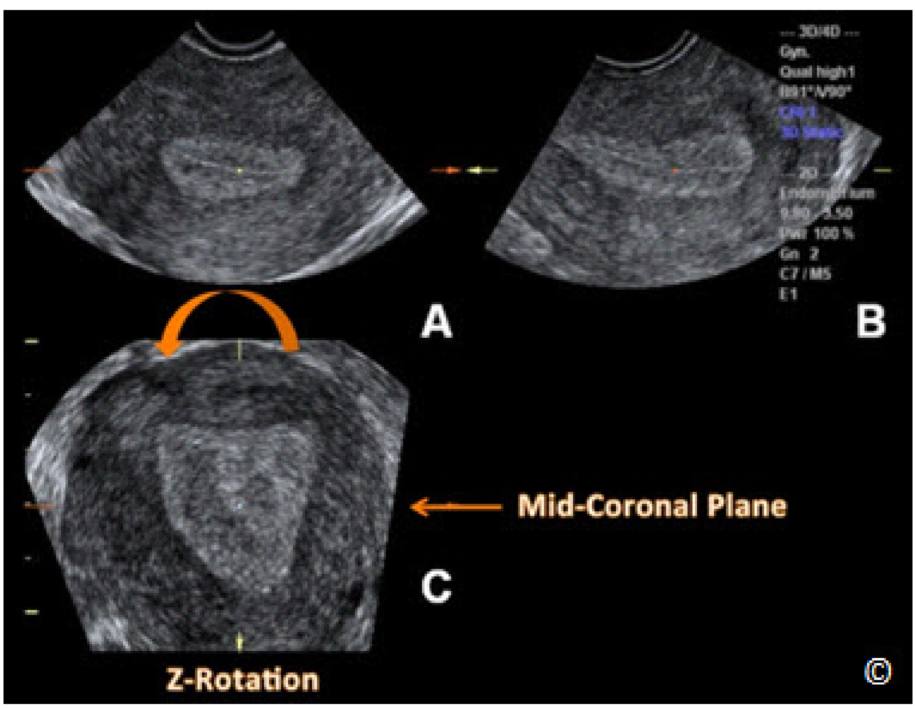


Figure 11.26: 3D volume of the uterus (same as in **Figure 11.22**) in multiplanar display. The final step (step 5) of the Z-technique involves applying Z rotation on plane C (curved arrow) to display the mid-coronal plane in the traditional orientation. Modified with permission from the American Institute of Ultrasound in Medicine (21).

Several authors have reported on the high accuracy of 3D ultrasound when comparing it with surgical findings in the diagnosis of uterine anomalies (22, 23). Furthermore, its accuracy compared to MRI has been established (24). We recommend 3D ultrasound as the modality of choice when evaluating a patient for a suspected uterine anomaly because of its relative low cost, lack of ionizing radiation or iodine contrast agents and excellent diagnostic capability, in addition to eliminating the need for laparoscopy in certain cases (25).

LEIOMYOMAS

Leiomyomas (fibroids) are the most common benign tumors encountered in gynecology as they are seen in about 20 – 30 % of women older than 35 years of age (26). By 50 years of age, about 70% of white women and more than 80% of black women will have had at least one leiomyoma with related significant symptoms in 15 to 30% of these women (26, 27). Histologically, leiomyomas consist of smooth muscle with varying amount of connective tissue and their growth is generally, estrogen dependent. The presence of leiomyosarcoma in a leiomyoma is rare and occurs in about 0.2% of cases. Leiomyomas are more prevalent in black women (26) and despite their estrogen dependency; only about 50 % show growth in association with pregnancy. In postmenopausal women, leiomyomas typically regress in size and are rarely of clinical concern. Leiomyomas have pseudocapsules, which are formed of compressed surrounding myometrium. Leiomyomas are usually multiple and most are asymptomatic and are discovered as palpable masses, or uterine enlargement, on routine gynecologic examination. On occasions, they are associated with abnormal uterine bleeding or pelvic pain.

Leiomyomas arise from the uterine myometrium and can occupy various anatomic positions within the uterus or surrounding structures. **Table 11.5** lists various types of leiomyomas in relation to their anatomic locations. The degree to which the leiomyoma projects into the endometrial cavity is of clinical importance as it helps to determine whether the leiomyoma can be resected hysteroscopically or not. In general, if the leiomyoma is protruding 50% or more into the endometrial cavity, hysteroscopic resection can be achieved. **Figure 11.27** is a schematic over an ultrasound image of various types of leiomyomas and **Figures 11.28** to **11.31** show various types of leiomyomas on ultrasound.

TABLE 11.5	Anatomic Locations of Leiomyomas (Figure 11.27)

- **Intramural:** The leiomyoma is within the myometrium with minimal or no bulging into the serosa or endometrium
- **Subserosal:** A significant portion of the leiomyoma is bulging into the serosal surface
- **Submucosal:** A significant portion of the leiomyoma is bulging into the endometrial cavity
- **Pedunculated:** The leiomyoma is exophytic and is attached to the uterus by a pedicle
- **Intracavitary:** The leiomyoma is within the endometrial cavity and is attached to the myometrium by a pedicle
- **Parasitic:** The leiomyoma is exophytic with blood supply obtained from an adjacent structure other than the uterus

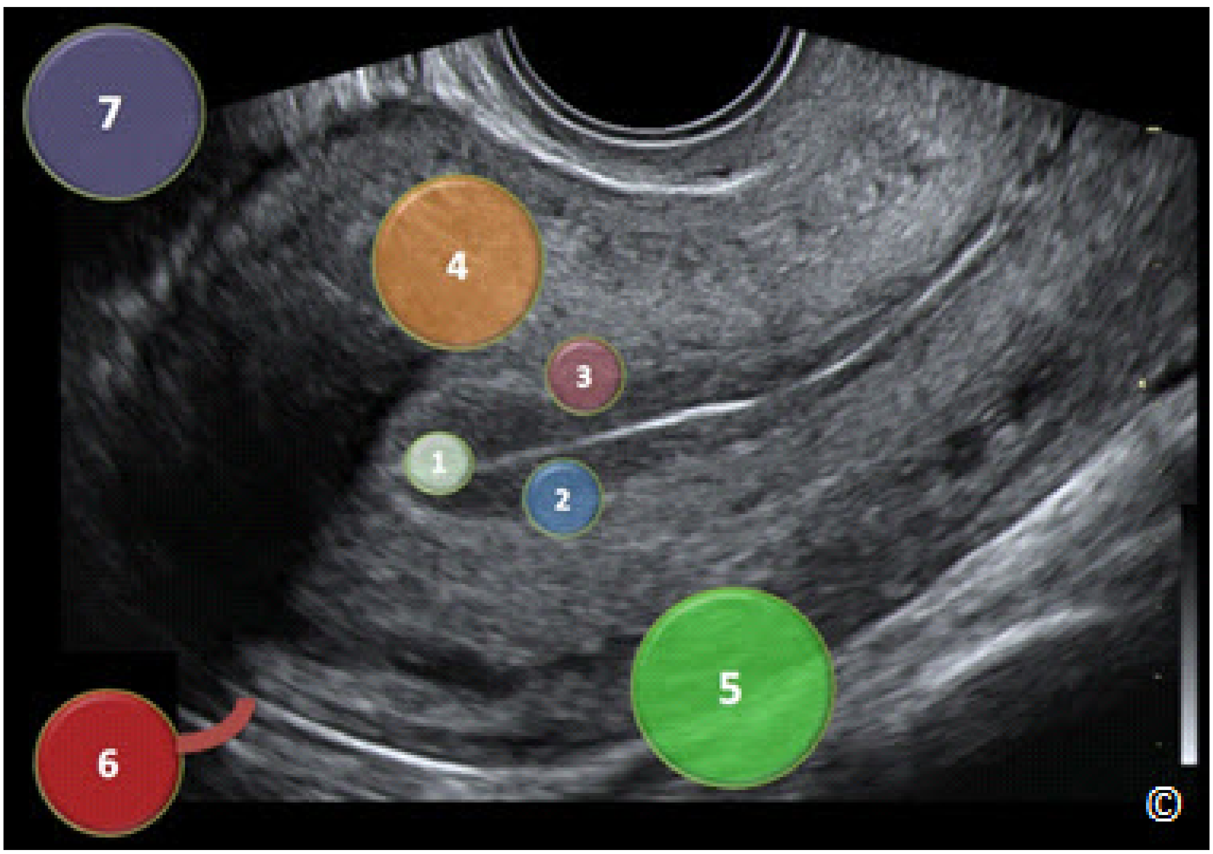


Figure 11.27: Transvaginal ultrasound of a midsagittal plane of the uterus with schematic overlay of leiomyomas to describe their anatomic locations. 1 = Intracavitary, 2 = Submucosal with > 50% into the endometrial cavity. 3 = Submucosal with < 50% into the endometrial cavity. 4 = Intramural. 5 = Subserosal. 6 = Pedunculated. 7 = Parasitic.

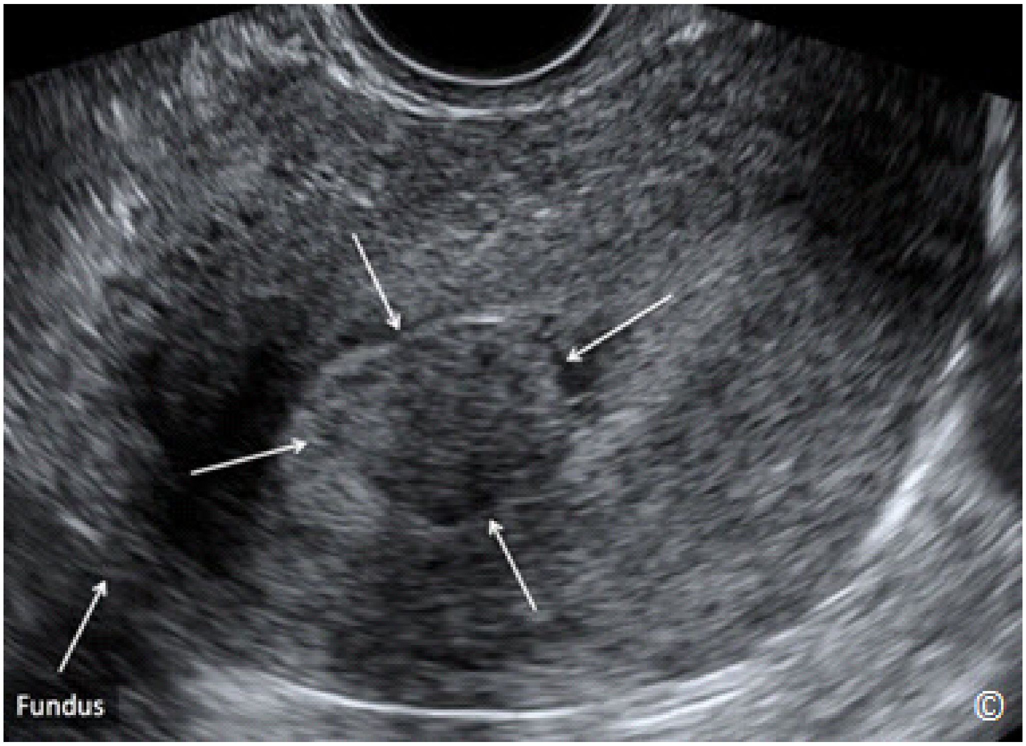


Figure 11.28: Transvaginal ultrasound of a midsagittal plane of the uterus showing a submucosal (intracavitary) leiomyoma (arrows). Uterine fundus is labeled for image orientation. See **Table 11.6** for sonographic features. Image is courtesy of Dr. Bernard Benoit.

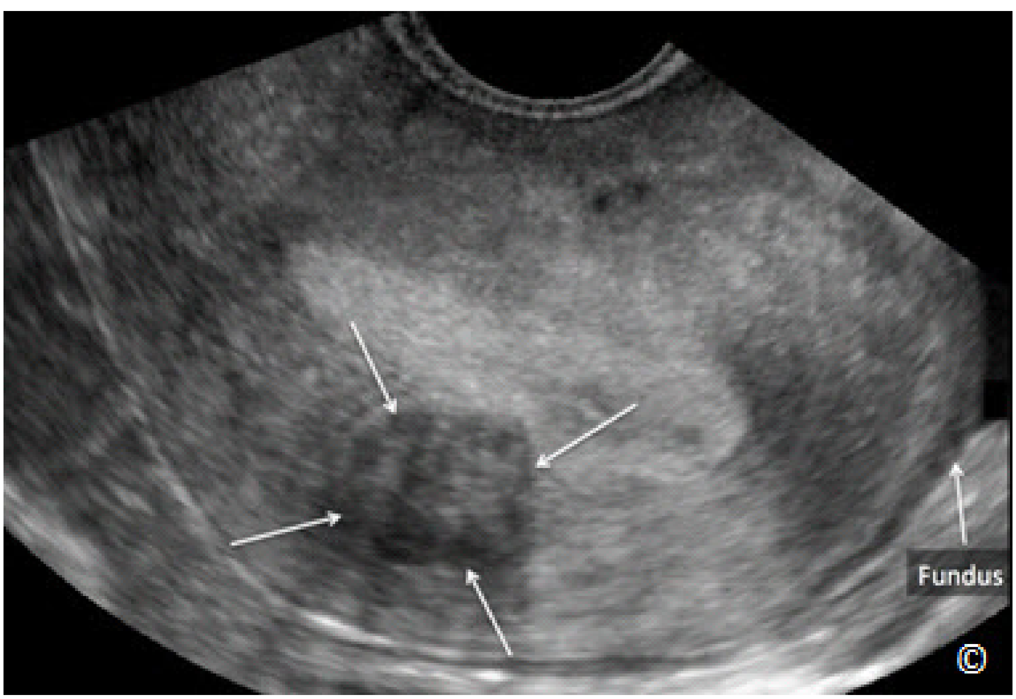


Figure 11.29: Transvaginal ultrasound of a midsagittal plane of the uterus showing an intramural leiomyoma (arrows). Uterine fundus is labeled for image orientation. See **Table 11.6** for sonographic features. Image is courtesy of Dr. Bernard Benoit.

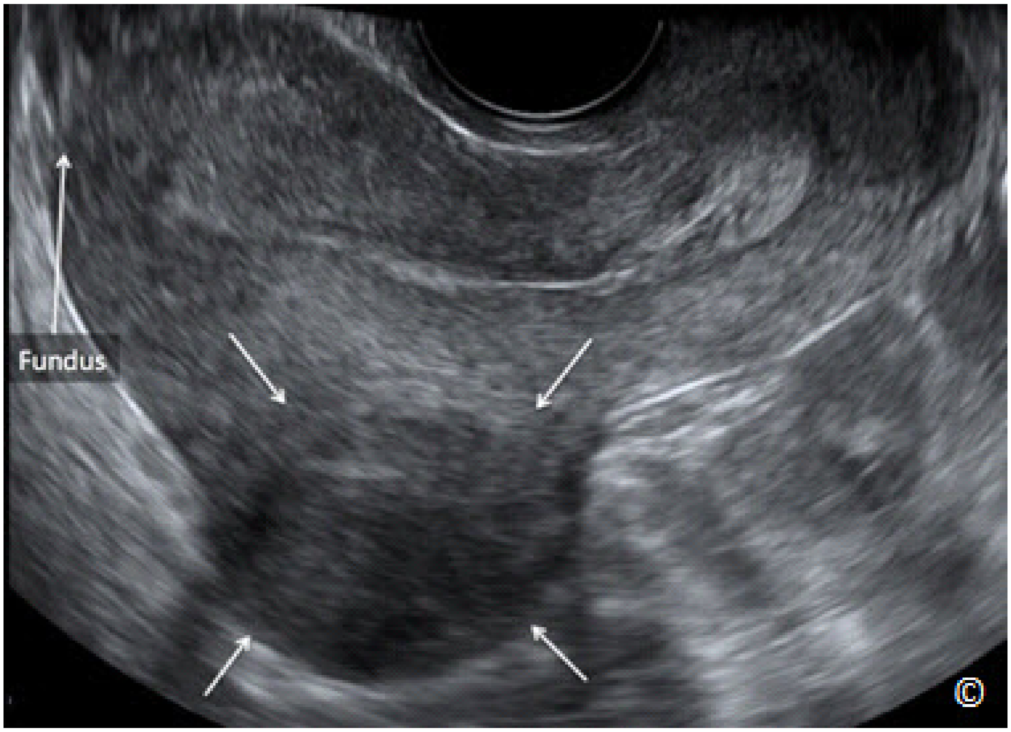


Figure 11.30: Transvaginal ultrasound of a midsagittal plane of the uterus showing a subserosal leiomyoma (arrows). Uterine fundus is labeled for image orientation. See **Table 11.6** for sonographic features. Image is courtesy of Dr. Bernard Benoit.

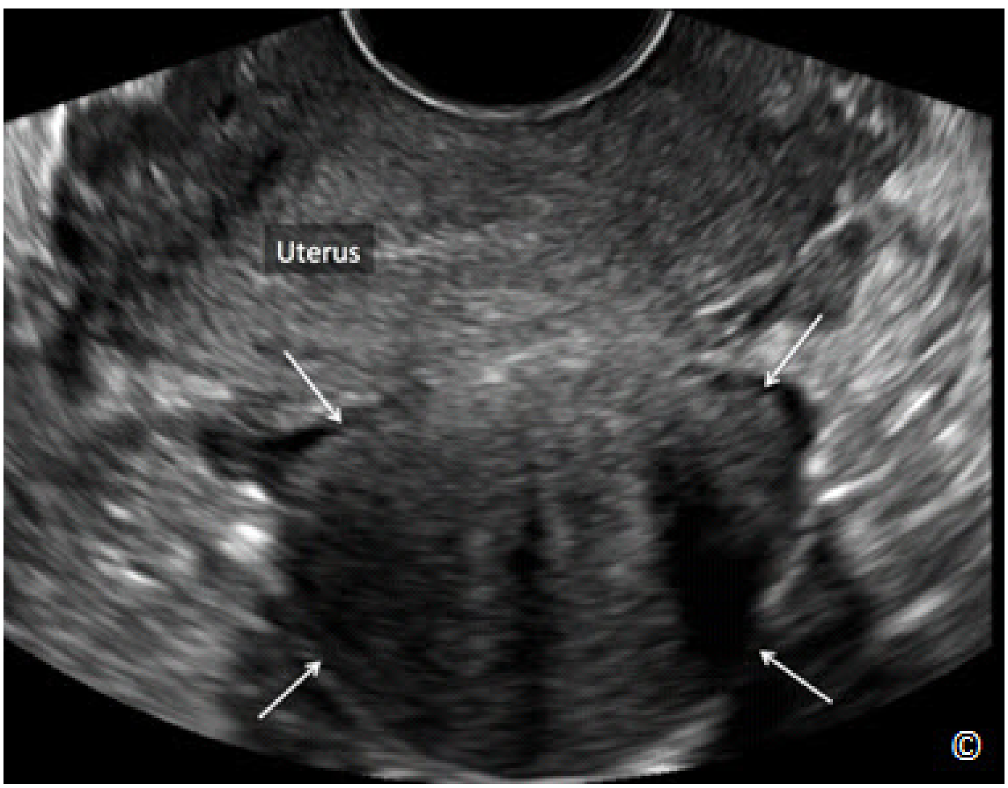


Figure 11.31: Transvaginal ultrasound of a midsagittal plane of the uterus showing a pedunculated leiomyoma (arrows) in a posterior location to the uterus. Uterine fundus is labeled for image orientation. See **Table 11.6** for sonographic features.

The sonographic features of leiomyomas are listed in **Table 11.6** and the various types of leiomyoma's degeneration are listed in **Table 11.7**. Hyaline degeneration is the most common and appears as anechoic areas within the central portion of a leiomyoma (**Figure 11.32**).

TABLE 11.6	Sonographic Features of Leiomyomas

- Solid echogenic mass arising from the uterine myometrium
- Well defined contour (pseudocapsule)
- Whorled appearance due to smooth muscle and connective tissue arranged in a concentric pattern
- Significant attenuation of ultrasound beam
- Characteristic shadow pattern described as "venetian blind shadowing" (**Figure 11.33**)
- Minimal to moderate vascularity on color Doppler
- When pedunculated, the solid leiomyoma tends to move with the uterus and distinctly from the ovary (**Clip 11.1**)
- Color Doppler can on occasions identify a stalk and connect it to the uterus in pedunculated leiomyomas

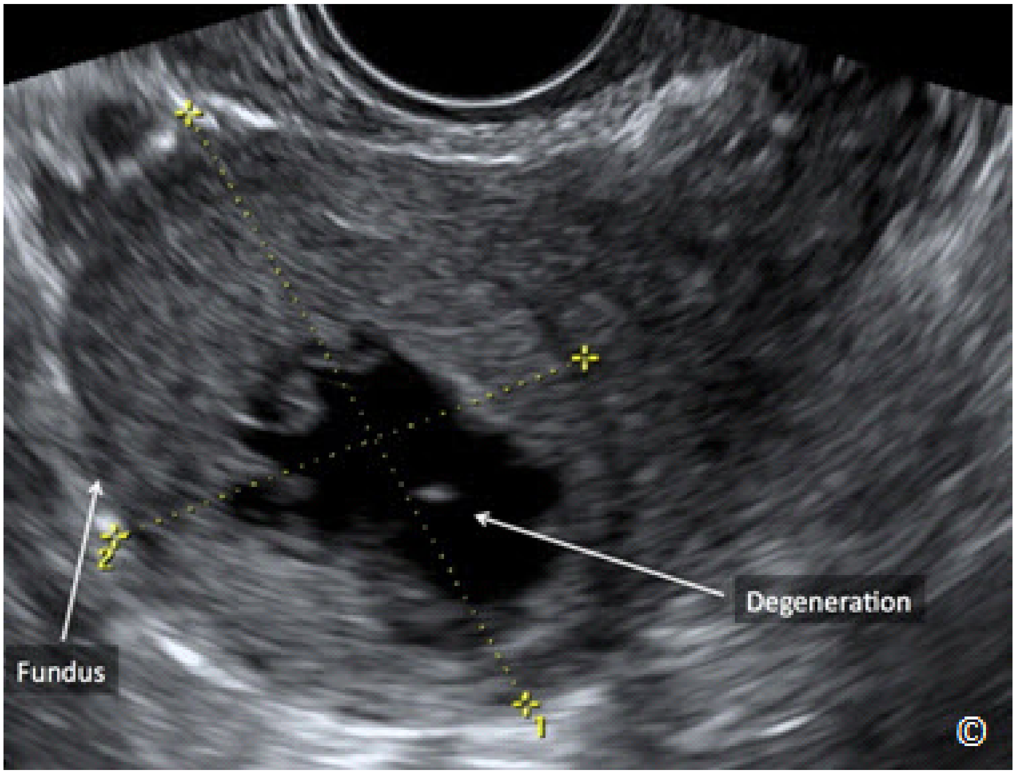


Figure 11.32: Transvaginal ultrasound showing a hyaline degeneration of an intramural leiomyoma (labeled). The uterine fundus is labeled for image orientation.

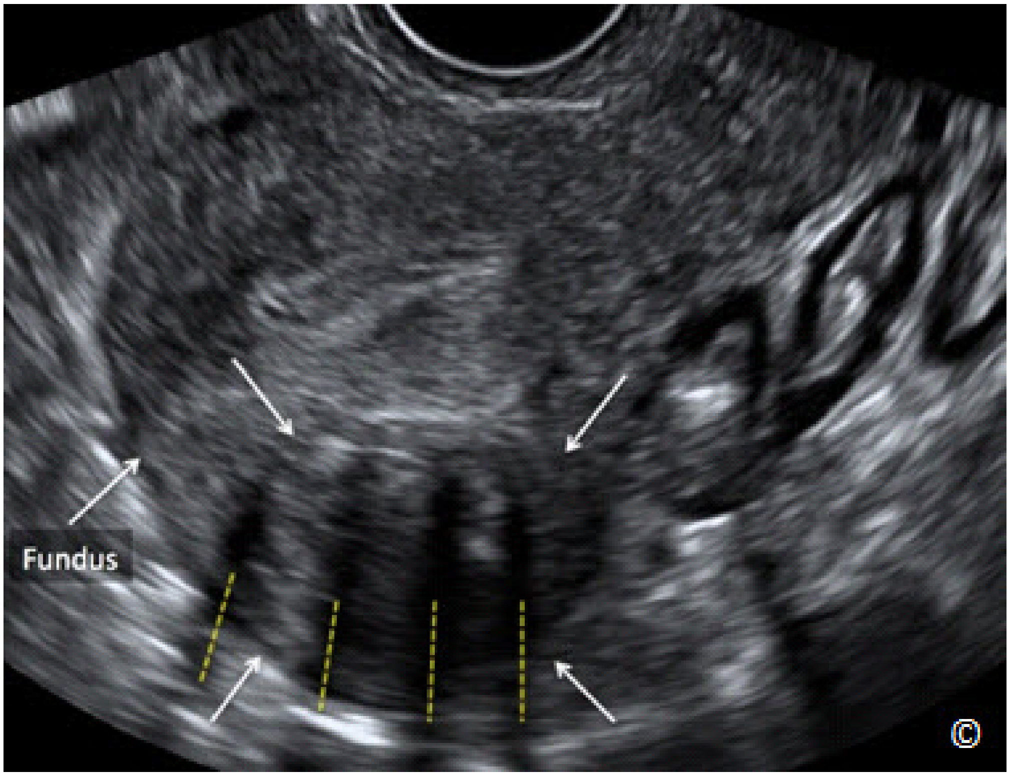


Figure 11.33: Transvaginal midsagittal plane of a uterus showing a subserosal leiomyoma (arrows). Note the typical leiomyoma shadowing described as "venetian blinds shadowing" (dashed lines). The uterine fundus is labeled for image orientation.

TABLE 11.7	Types of Leiomyoma Degeneration
- Atrophic - Hyaline - Carneous - Myxoid - Calcific - Cystic - Hemorrhagic	

ENDOMETRIAL ABNORMALITIES

Abnormal Uterine Bleeding:

Abnormal uterine bleeding (AUB) is a term that describes abnormal menstrual flow in women of reproductive age. AUB can be related to abnormal volume, duration, frequency and regularity of menstrual flow. In an effort to standardize diagnosis and management of AUB, the International

Federation of Gynecology and Obstetrics (FIGO) in 2011, introduced a new classification of AUB known by the acronym PALM-COEIN, which stands for polyps, adenomyosis, leiomyoma, malignancy (hyperplasia), coagulopathy, ovulatory dysfunction, endometrial iatrogenic and not yet classified (28). The American Congress of Obstetrics and Gynecology (ACOG) supported the adoption of this classification in the practice bulletin on diagnosis of AUB in reproductive age women (29). The term dysfunctional uterine bleeding, which has been commonly used to describe AUB, should be abandoned (28, 29).

The evaluation of women with AUB is beyond the scope of this textbook, but in general should include a history, physical examination, laboratory and imaging studies and endometrial sampling when indicated, based upon the age of symptomatic women. There is insufficient evidence to recommend the use of transvaginal ultrasound for endometrial thickness evaluation in AUB in women of reproductive age unless there are risk factors for endometrial carcinoma. Transvaginal ultrasonography is useful however as a screening test to assess the endometrial cavity for leiomyomas and polyps. In postmenopausal women, transvaginal ultrasound has the ability to exclude malignancy when the endometrial lining is uniform and is 4 mm or less. This is discussed in more details later in this chapter.

Endometrial Polyps and Submucosal Leiomyomas:

Common focal intracavitary endometrial lesions include polyps and submucosal leiomyomas as they account for 30% and 10% of causes of postmenopausal bleeding respectively (30). Sonohysterography has been shown to be a superior imaging modality in the evaluation of intracavitary endometrial lesions such as polyps (**Figure 11.34**) and leiomyomas, when compared to transvaginal ultrasound alone (31). The efficacy of sonohysterography in the diagnosis of endometrial polyps and submucosal leiomyomas has been shown to be equal to hysteroscopy in some series (32).

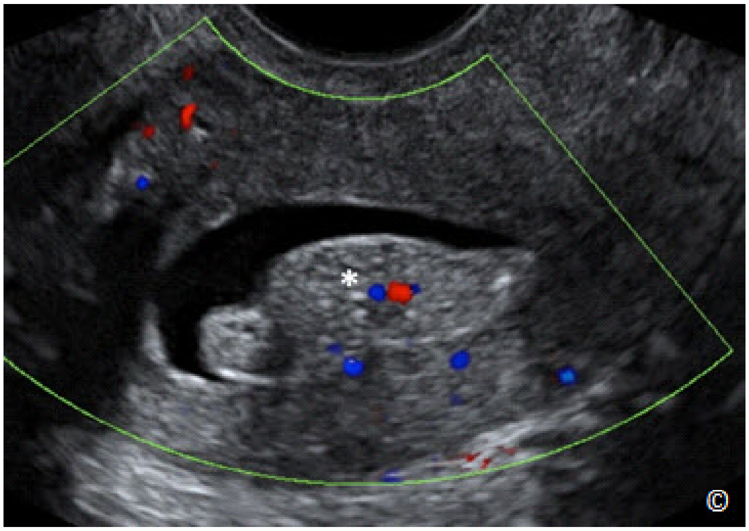


Figure 11.34: Transvaginal sonohysterography with color Doppler of a midsagittal plane of the uterus showing an endometrial polyp (asterisk). Note the increased echogenicity of the polyp as compared to myometrial tissue.

Endometrial polyps appear on sonohysterography as more echogenic than the surrounding myometrium, completely contained within the endometrial cavity with no extension into the myometrium, homogeneous in echo texture with a narrow base of attachment to the underlying myometrium (**Figure 11.34**). Color Doppler may demonstrate a vascular pedicle at the base of the polyp in most cases (**Figure 11.35** and **11.36**). Cystic changes within a polyp are occasionally seen and polyps can also be seen in the isthmic portion of the cavity (**Figure 11.36**) and endocervical canal. Submucosal leiomyomas appear on sonohysterography as less echogenic than the surrounding endometrium, broad-based and lift the surrounding endometrium as they project to varying degrees into the cavity (**Figure 11.37**). Given that submucosal leiomyomas arise from the subendometrial myometrium, a portion of the leiomyoma extends into the myometrium: a differentiating feature from an endometrial polyp. Submucosal leiomyomas tend to shadow the ultrasound beam, another important distinctive feature from endometrial polyps (**Figure 11.37**). **Table 11.7** lists differentiating features of polyps and submucosal leiomyomas. The degree to which the submucosal leiomyoma projects into the endometrial cavity is of clinical relevance. Extension of a leiomyoma by more than 50% of its surface into the cavity allows for possible hysteroscopic resection.

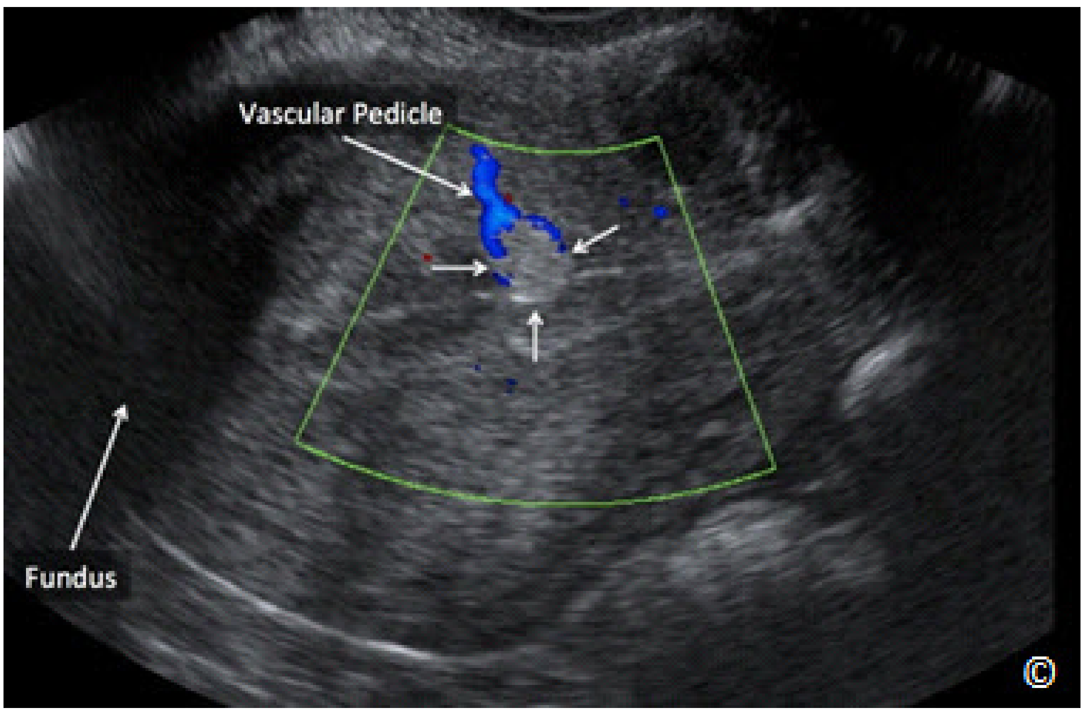


Figure 11.35: Transvaginal ultrasound with color Doppler of a midsagittal plane of the uterus showing a small endometrial polyp (arrows). Note the increased echogenicity of the polyp as compared to myometrial tissue and a vascular pedicle noted on color Doppler. The uterine fundus is labeled for image orientation.

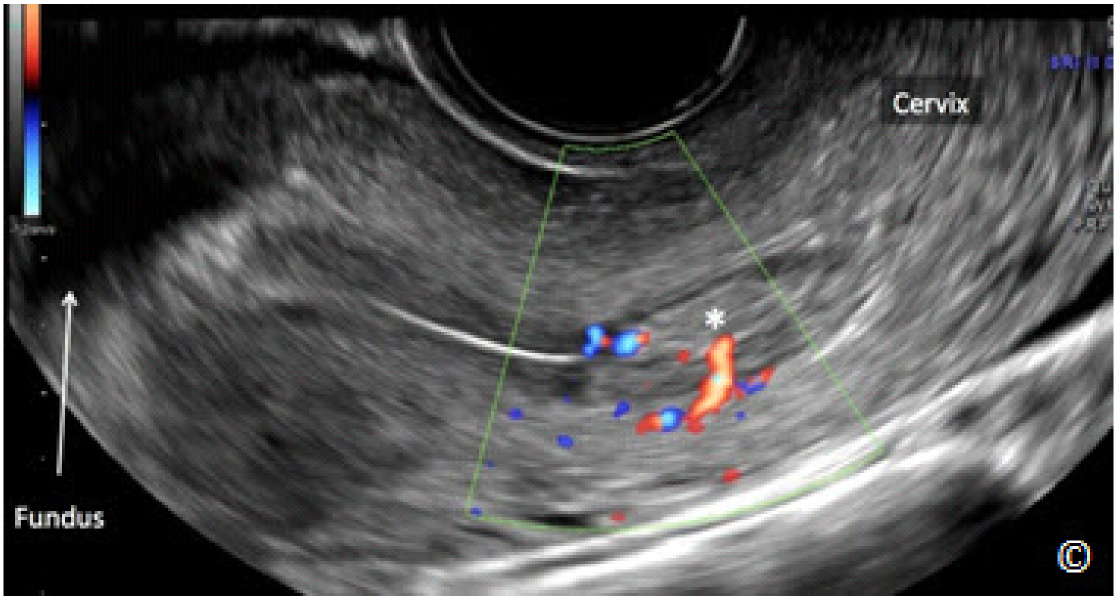


Figure 11.36: Transvaginal ultrasound with color Doppler of a midsagittal plane of the uterus showing an endometrial polyp (asterisk) in the isthmic portion of the endometrial cavity. Note the presence of a vascular pedicle on color Doppler. The uterine fundus is labeled for image orientation.

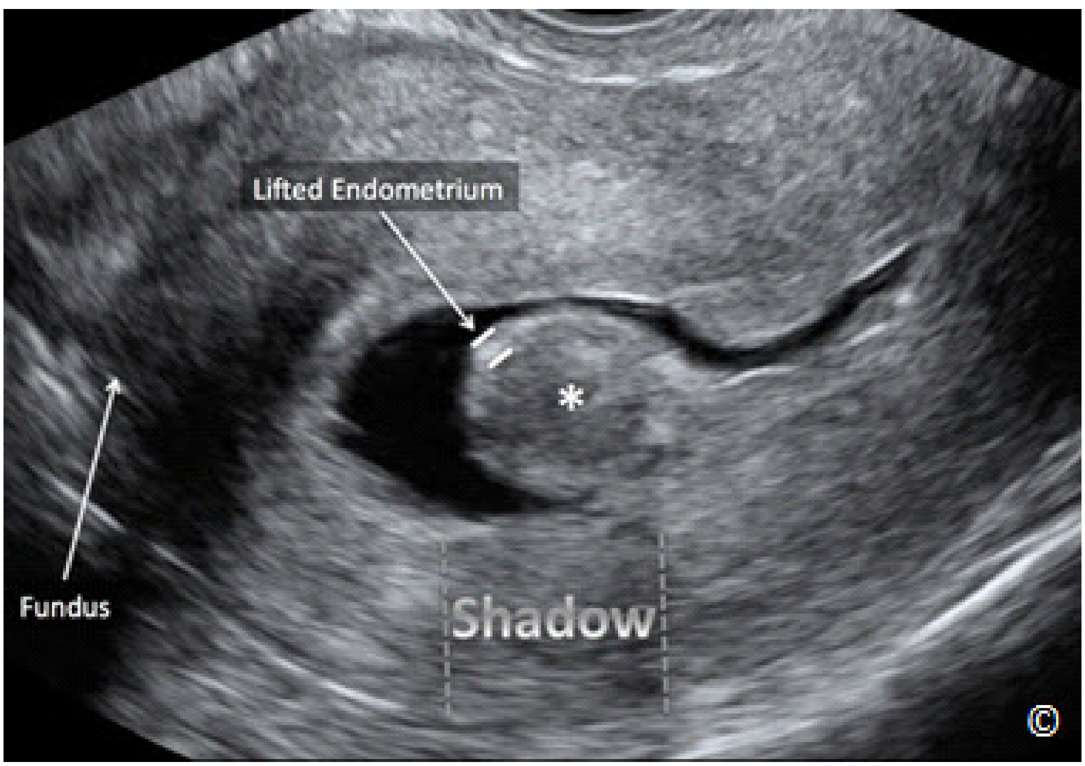


Figure 11.37: Transvaginal sonohysterography of a midsagittal plane of the uterus showing a submucosal leiomyoma (asterisk). Note that the echogenicity of the leiomyoma is comparable to that of the myometrium. The lifted endometrium (labeled – equal sign) is noted surrounding the leiomyoma in the endometrial cavity. Also note the shadowing (shadow – dashed lines) from the leiomyoma. The uterine fundus is labeled for image orientation. Image is courtesy of Dr. Bernard Benoit.

TABLE 11.7	Differentiating Sonographic Features of Endometrial Polyps and Submucosal Leiomyomas

- Polyp are contained within the endometrial cavity whereas Leiomyomas extend into the myometrium
- Echogenicity of polyps is similar to endometrial lining whereas echogenicity of leiomyomas is similar to myometrium (less)
- Polyps tend to have a visible vascular pedicle on color Doppler and are homogeneous in echotexture
- Leiomyomas lift the endometrial lining
- Leiomyomas tend to shadow the ultrasound beam

Endometrial Adhesions and Retained Products of Conception:

Other endometrial pathology amenable to diagnosis by sonohysterography includes intrauterine adhesions, and retained products of conception. Intrauterine adhesions are clearly visible on sonohysterography as thick or thin echogenic bands that attach to the endometrial walls (**Figure 11.38**). Sonohysterography is the best imaging modality for the detection of intrauterine adhesions (33) and should be considered in patients with prior intrauterine instrumentation. Retained products of conception appear as an echogenic mass within the endometrial cavity (**Figure 11.39**). They are typically seen in women following an abortion, a miscarriage or a delivery.

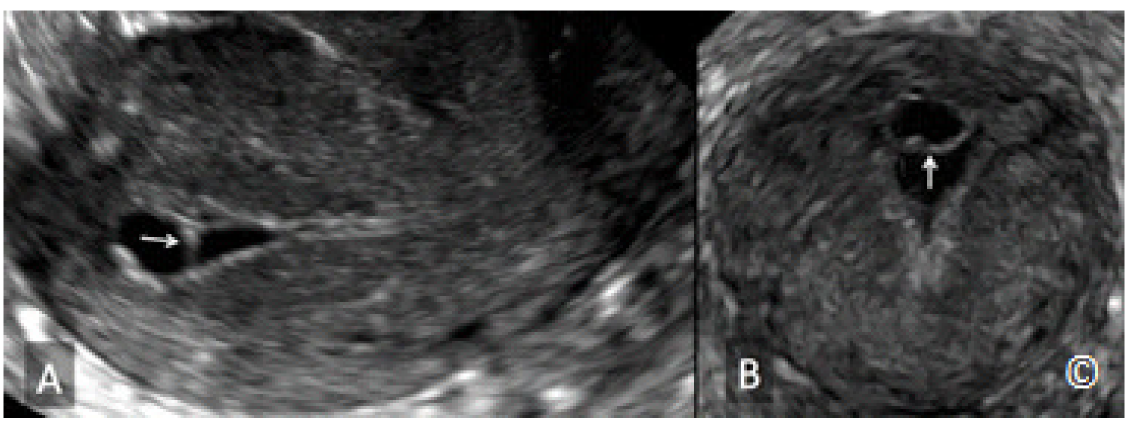


Figure 11.38: Transvaginal sonohysterography in a patient with suspected endometrial adhesions. Note the presence of a thin reflective membrane in the sagittal (arrow in A) and coronal (arrow in B) plane. These planes were obtained from a 3D volume.

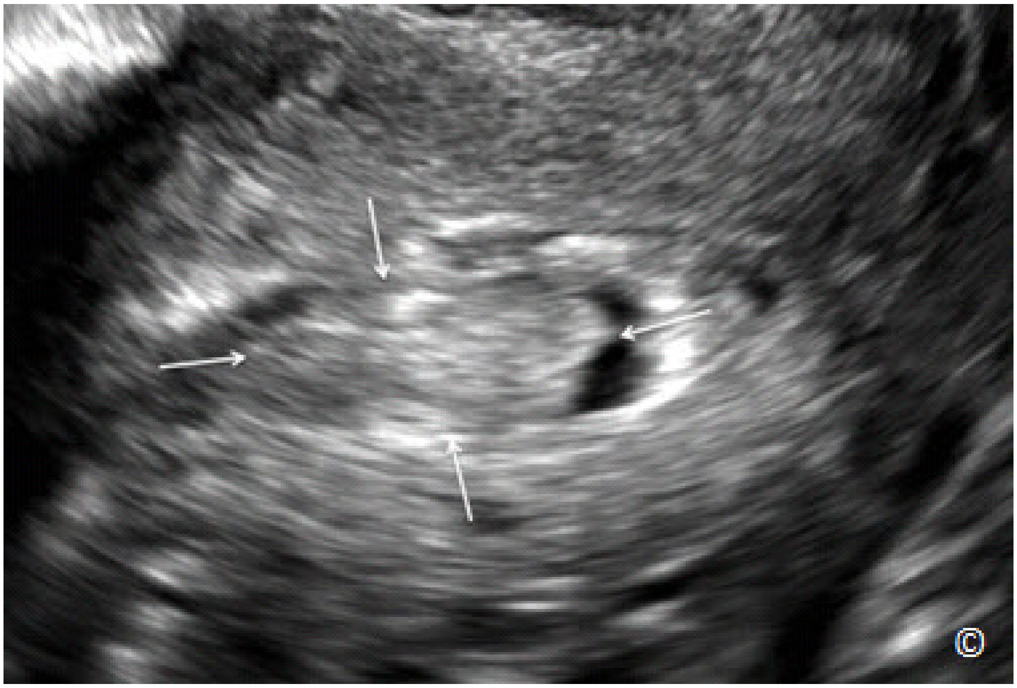


Figure 11.39: Transvaginal sonohysterography of the uterus in sagittal plane showing an echogenic mass (arrows) suggestive of retained products of conception. This patient had a complicated delivery 5 weeks prior.

Endometrial Hyperplasia and Cancer:

Endometrial cancer is the most common gynecologic cancer in the United States, with vaginal bleeding being the most common presenting symptom (34, 35). When postmenopausal women present with vaginal bleeding, a systemic approach should be performed to rule-out endometrial cancer or hyperplasia. An endometrial thickness that is 4 mm or less on a transvaginal ultrasound in women presenting with postmenopausal bleeding, practically excludes endometrial cancer and further endometrial evaluation is not warranted. Transvaginal ultrasound is therefore a reasonable first approach to the evaluation and management of postmenopausal bleeding. If the endometrial thickness is greater than 4 mm, further evaluation is needed with endometrial sampling, sonohysterography or hysteroscopy. If endometrial sampling has been performed first and insufficient tissue was obtained for diagnosis, a transvaginal ultrasound can be performed and if it shows an endometrial thickness of 4 mm or less, no further evaluation is needed (36). The significance of an endometrial thickness of greater than 4 mm in asymptomatic women is unclear and should not prompt further work-up unless the patient is at a significantly increased risk for endometrial cancer (37). It is important to note that endometrial thickness should only be measured when a midsagittal plane of the uterus is obtained with clear depiction of the endometrial thickness from the fundal to the uterine isthmic / cervical area (**Figure 11.13**). If such a plane cannot be obtained, or visualization of the endometrial thickness is unclear, transvaginal ultrasound cannot be used in the evaluation of women with postmenopausal bleeding and alternate methods should be obtained. The validity of transvaginal ultrasound as a screening tool for endometrial cancer has not been established and thus it should not be used for this clinical indication.

Endometrial hyperplasia can be diffuse or focal. Diffuse endometrial hyperplasia will appear on sonohysterography as thickening of the endometrium. Focal endometrial hyperplasia on the other hand is seen as a broad-based echogenic mass that does not distort the endometrial-myometrial junction. Differentiating focal endometrial hyperplasia from an endometrial polyp can at times be difficult. Endometrial cancer has similar sonographic characteristics to endometrial hyperplasia or an enlarged polyp, with the exception of myometrial invasion, which can be occasionally visible on ultrasound. **Figures 11.40** to **11.42** represent transvaginal ultrasounds of endometrial and uterine cancers.

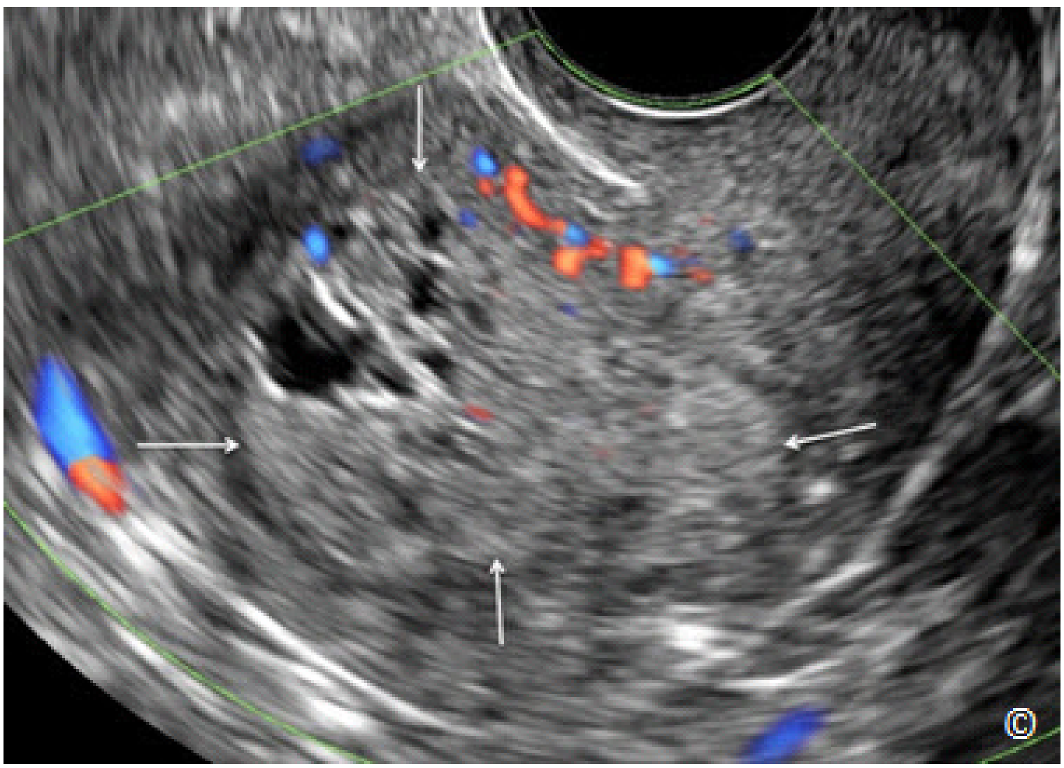


Figure 11.40: Transvaginal ultrasound of a sagittal plane of the uterus in a woman with endometrial cancer. Note the enlarged, heterogeneous and thickened endometrium (arrows).

Figure 11.41: Transvaginal sonohysterography of a sagittal plane of the uterus in a woman with endometrial cancer. Note the multiple papillary projections (arrows) in the endometrial cavity.

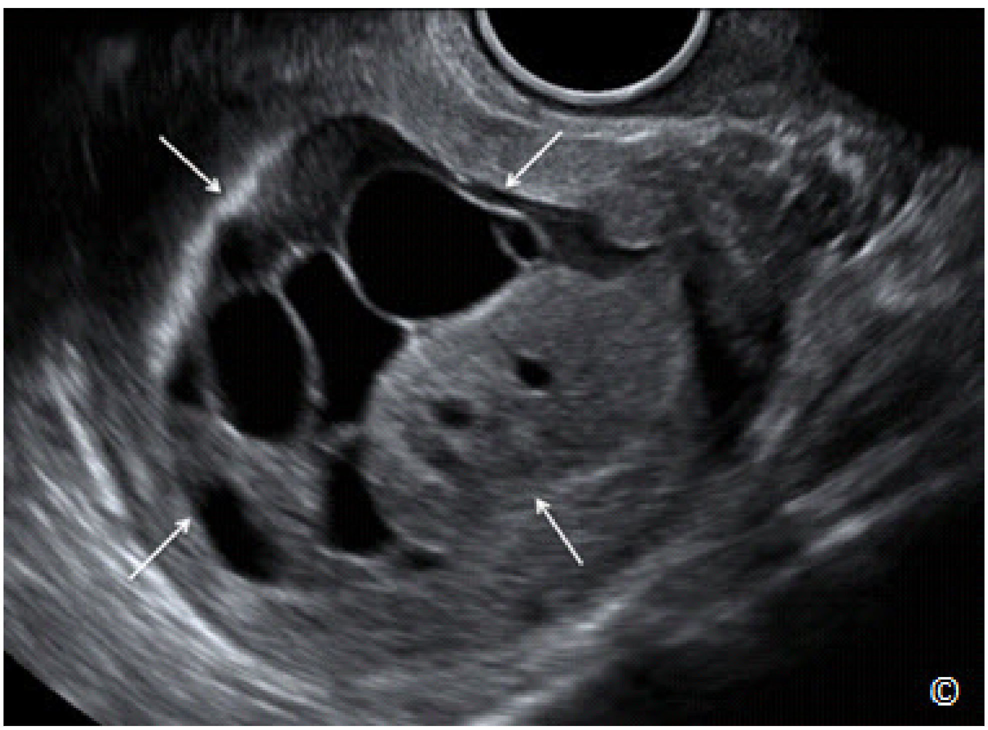


Figure 11.42: Transvaginal ultrasound of a parasagittal plane of the uterus in a patient presenting with a uterine mass. Note the presence of a complex mass (arrows), which was a uterine stromal sarcoma on pathologic evaluation.

Arteriovenous Malformations:

Uterine arteriovenous malformations (AVM) are rare and represent direct communications between the arterial and venous system. They typically arise following instrumentation of the endometrial cavity, commonly in association with pregnancy loss or delivery. On occasions, they are associated with malignancies, infections or retained products of conception in molar pregnancies (38, 39). AVM can also be congenital in nature and as such, they are less common and symptomatic than the acquired variety (40).

The most common clinical presentation of AVM is heavy vaginal bleeding in patients who had instrumentation of the endometrial cavity following a pregnancy. Other less common symptoms include pelvic pain and dyspareunia. The diagnosis of AVM is best achieved by a transvaginal ultrasound with color and pulsed Doppler. On grey scale ultrasound, AVM are seen as anechoic spaces within the uterus, with irregular contour, typically located within the myometrium near its junction with the endometrium (**Figure 11.43**). Color Doppler shows turbulent flow within the anechoic spaces with aliasing (**Figure 11.44**), and pulsed Doppler demonstrates high-velocity, low impedance flow patterns (**Figure 11.45**). Color and pulsed Doppler is helpful in confirming the presence of AVM and also in differentiating AVM from pseudoaneurysms. Pseudoaneuryms, which can also occur following instrumentation of the uterine cavity, have swirling arterial blood in them with high-velocity and high impedance blood flow patterns on color and pulsed Doppler evaluation (41).

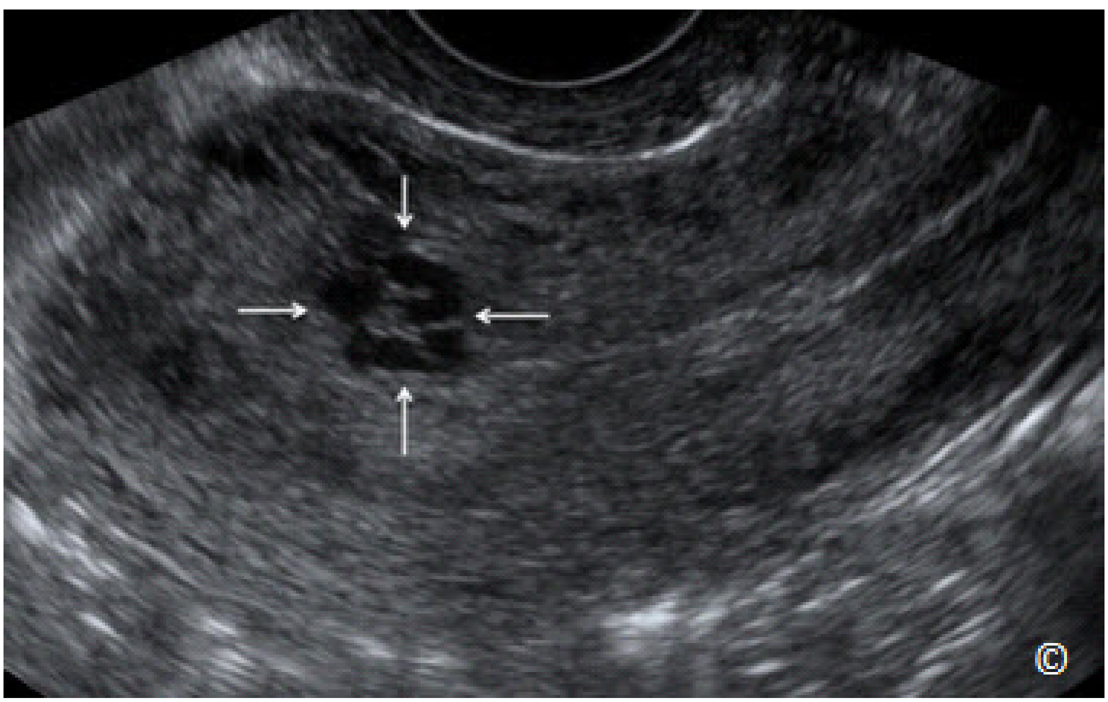


Figure 11.43: Transvaginal ultrasound of a sagittal plane of the uterus showing an arterio-venous malformation (AVM) (arrows). Note the sonographic appearance of AVM as anechoic spaces, with irregular contour, located within the myometrium near its junction with the endometrium.

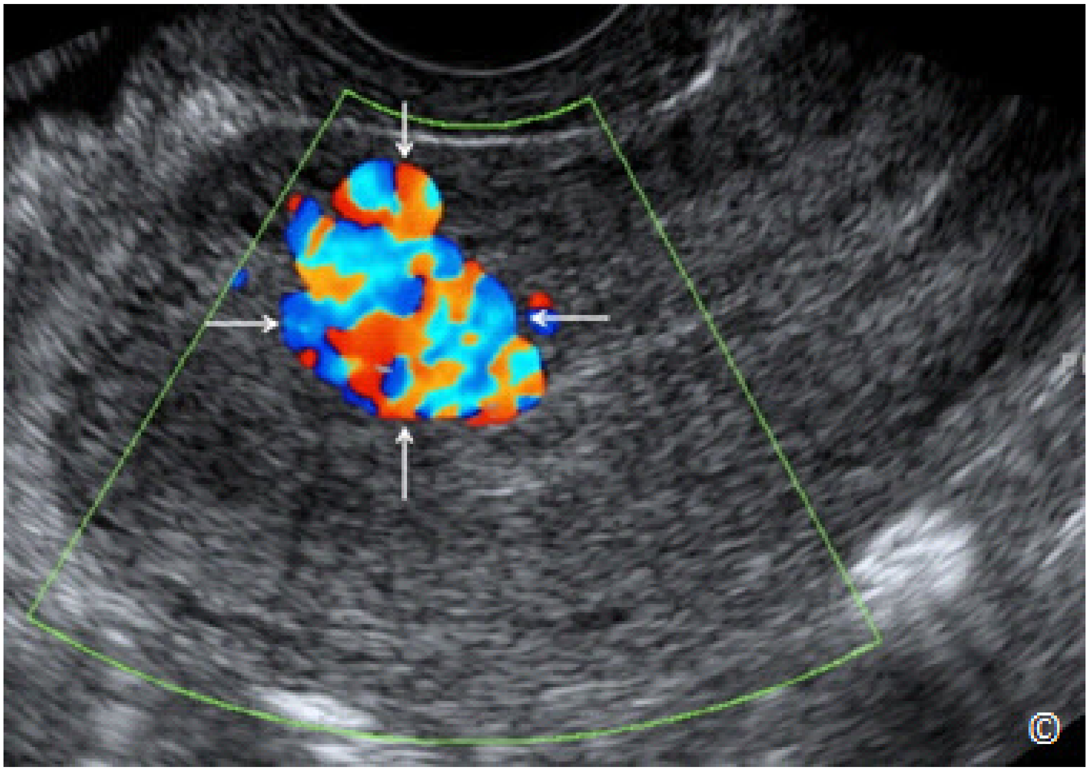


Figure 11.44: Transvaginal ultrasound with color Doppler of a sagittal plane of the uterus showing the same arterio-venous malformation (AVM) (arrows) as that in **Figure 11.43.** Note the presence of blood flow within the AVM with turbulence and aliasing.

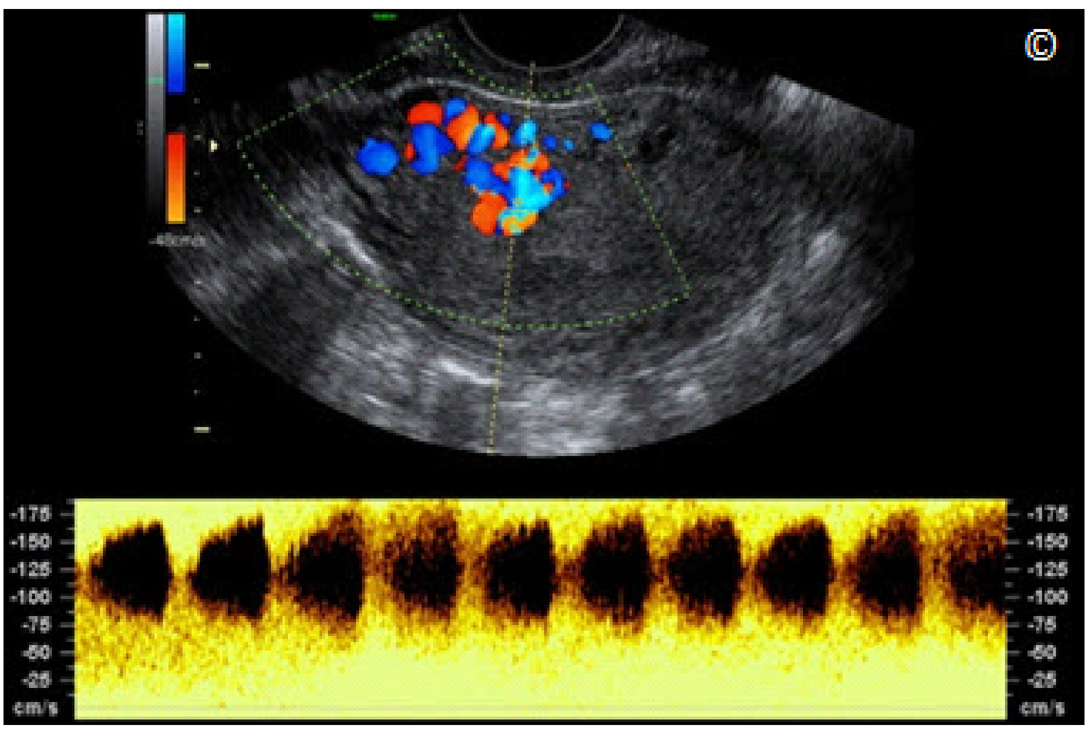
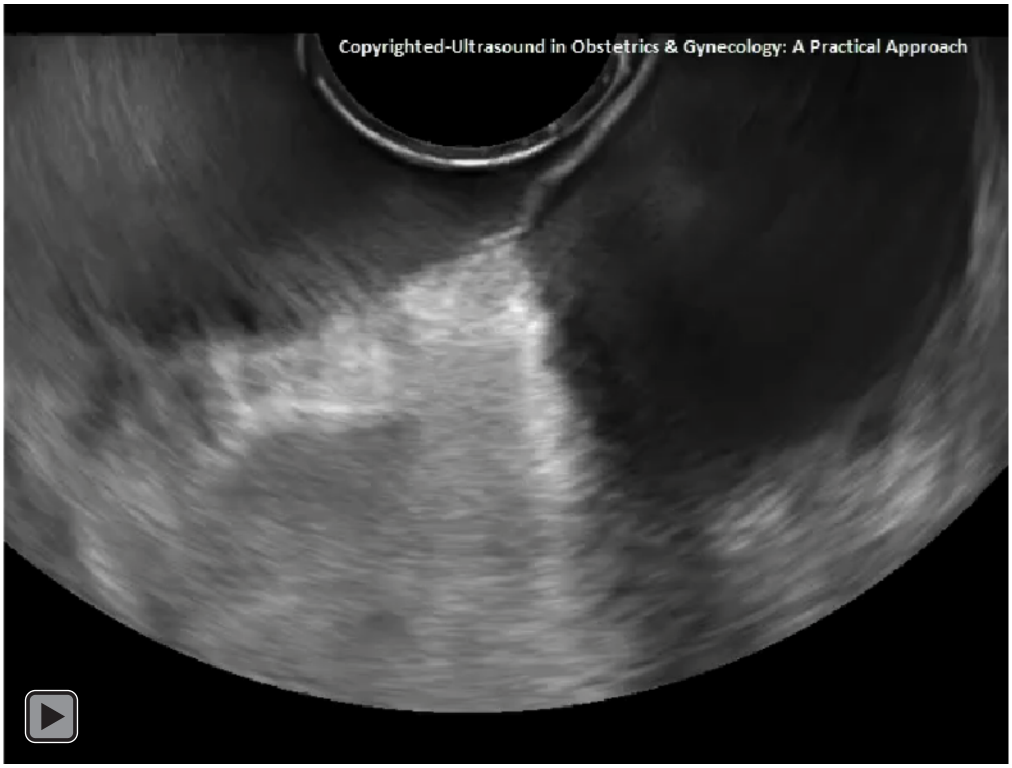


Figure 11.45: Transvaginal ultrasound with color and pulsed Doppler of a sagittal plane of the uterus showing the same arterio-venous malformation (AVM) (arrows) as that in figure 11.43. Note the pulsed Doppler waveforms showing low-impedance, high velocity (100 cm/sec) flow.

Management of AVM should include a conservative approach following diagnosis, assuming that the bleeding is not very heavy and the patient is not significantly anemic. Our experience and that of others suggest resolution of AVM in a significant number of women with conservative management over a 2-5 months period (42). Transcatheter arterial embolization is the preferred method of treatment if conservative management fails, or bleeding is very heavy. Transcatheter arterial embolization has a reported success rate of 50 – 70 % (43). Long-term prognosis is good for women with AVM that regressed following conservative management or with arterial embolization with reports of successful pregnancies (44).

CLIP 11.1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