Manual of diagnostic ultrasound

During the last decades, use of ultrasonography became increasingly common in medical practice and hospitals around the world, and a large number of scientific publications reported the benefit and even the superiority of ultrasonography over commonly used X-ray techniques, resulting in significant changes in diagnostic imaging procedures.

With increasing use of ultrasonography in medical settings, the need for education and training became essential. WHO took up this challenge and in 1995 published its first training manual in ultrasonography. Soon, however, rapid developments and improvements in equipment and indications for the extension of medical ultrasonography into therapy indicated the need for a totally new ultrasonography manual.

The manual (consisting of two volumes) has been written by an international group of experts of the World Federation for Ultrasound in Medicine and Biology (WFUMB), well-known for their publications regarding the clinical use of ultrasound and with substantial experience in the teaching of ultrasonography in both developed and developing countries. The contributors (more than fifty for the two volumes) belong to five different continents, to guarantee that manual content represents all clinical, cultural and epidemiological contexts.

This new publication, which covers modern diagnostic and therapeutic ultrasonography extensively, will certainly benefit and inspire medical professionals in improving ‘health for all’ in both developed and emerging countries.

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Manual of diagnostic ultrasound

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Gynaecology

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Gynaecological ultrasonography is a non-invasive imaging technique that can be used:

- in the diagnostic work-up of pelvic masses suspected on the basis of history and pelvic clinical examination;
- in the diagnostic work-up of dysfunctional or infective diseases that involve or can involve the pelvis;
- in the differential diagnosis of other acute abdominopelvic diseases (appendicitis, diverticulitis, inflammatory bowel diseases);
- in the peri- and postmenopausal diagnostic evaluation of women with atypical uterine bleeding, in order to define the macroscopic characteristics of the endometrium and uterine cavity;
- in ovarian and endometrial surveillance of women at high-risk for ovarian and endometrial cancer (familial, drugs);
- in monitoring spontaneous or drug-induced ovulation;
- in monitoring therapy and surgery.

Sonography plays an important role in the detection of gynaecological disorders and is used widely with clinical examinations but also for first-line imaging to give an accurate indication for more sophisticated diagnostic techniques or more invasive endoscopic procedures. Technological advances have made it possible to use transabdominal (suprapubic) sonography with transvaginal or transrectal scanning.

The choice of an ultrasound examination should be guided by clinical indications, but the widespread availability of ultrasound equipment leads many specialists to request an ultrasound scan on almost all women, to complete their clinical examination.

Transvaginal scanning is now the examination technique of choice. Some conditions do not allow or limit transvaginal scanning: the integrity of the hymen, women’s refusal to undergo an imaging technique that they consider invasive, or the presence of phlogistic and cicatricial processes involving the vaginal walls that could make the transducer’s movements painful or limit them. Uterine bleeding is not a contraindication for ultrasound examination, even for suspected miscarriage.
In such cases, women should be reassured that transvaginal scanning is a harmless imaging technique that can help to clarify the causes of bleeding.

Transabdominal ultrasound should be considered for use with transvaginal scanning in abdominopelvic neoformation that cannot be explored completely with transvaginal ultrasound and when a woman’s condition does not allow endovaginal access.

Transrectal scanning is seldom used but may be useful when transvaginal scanning cannot be performed or to study the vaginal walls, the cervix, the parametria and the vaginal cuff after hysterectomy.

**Preparation and scanning techniques**

The techniques of choice for studying the uterus and ovaries are transabdominal and transvaginal ultrasound.

**Transabdominal ultrasound**

Transabdominal examination is performed with real-time, 2.5- to 5-MHz convex or sectoral transducers, depending on the woman’s age and body. Modern devices with multi-frequency transducers allow optimization of the ultrasound frequency to the woman’s body size and the structures to be studied. Convex transducers are widely used, although sectoral transducers may be better in some cases, such as abundant subcutaneous fat or a pendulous abdomen.

The examination should be performed with optimal bladder filling, generally obtained when the bladder covers the uterine fundus. A full bladder is needed as an acoustic window to displace the intervening bowel but also to decrease uterine physiological anteversion, bringing it into a better position for ultrasound scanning (Fig. 3.1). Scant filling is unfavourable, but hyperdistention of the bladder must be avoided as well because the uterus and adnexa are compressed and displaced into a deep location far from the skin plane. Hyperhydration is also to be avoided, because some fluid effusion may collect in the pelvis and simulate a disease state, and bowel loops may appear distended by fluid.

When appropriate bladder filling has been obtained, the operator performs longitudinal scans along the cervix–fundus of uterus axis and transversal scans along axial planes. The ovaries have a variable position and should be sought with appropriate paramedian-oblique ultrasound scans. Hypogastric vessels are important landmarks for the ovaries, because they run back and lateral to them (Fig. 3.2). The operator should be able to recognize possible artefacts, for example acoustic shadowing by enteric gas, that can create empty signal areas and simulate cysts; furthermore, a hyperdistended loop of bowel could simulate adnexal disease.

If the uterus is retroverted, its fundus is situated in a back position, far from the transducer and with an adverse ultrasound incidence. The fundus might thus appear less echogenic than the remaining myometrium, simulating a fibroid. The operator should distinguish these false aspects from real disease on the basis of his or her experience, perhaps repeating the examination or performing transvaginal scanning.
Transvaginal ultrasound

Transvaginal scanning is the best method for studying the uterus and adnexa. The woman must have an empty bladder, which will result in a shorter wait and less discomfort. The operator can also perform transabdominal scanning before a transvaginal scan.

Unlike transabdominal scanning, where the bladder must be filled or the bowel opportunistically cleaned, in transvaginal scanning no particular preparation is requested. The only advice is to empty the bladder soon before starting the examination, if it has been preceded by a transabdominal study. In this way, the woman’s discomfort is reduced and the transducer is not too far from the pelvic structures that are to be examined. Moreover, a full bladder can displace or compress adjacent organs, inducing distortions that can lead to an erroneous diagnosis. While the transabdominal technique is characterized by wide transducer inclination along
various angles and allows the examiner to visually assess the scan plane, during transvaginal scanning the transducer’s movements are limited and consist mainly of shifting the transducer along the sagittal and transverse axis or rotation.

The examination is done with the woman in the gynaecological position, ideally on a suitable bed with leg rests. If this is not available, the woman should remain supine with raised knees, legs wide apart and with the pelvis raised by a pillow, so that the bed does not stop the transducer’s movements. The abdomen and genitals should be covered with a sheet to reduce psychological discomfort. In this position, the Douglas cavity is no longer the most declivous site in the abdomen, so any free fluid can move upwards and may not be detected; to avoid this, it is useful to bend the back by about 30°.

Convex transducers with a high frequency (5–7.5 MHz) are used, with crystals set in the extremity. Before the transducer is inserted into the vagina, its distal extremity should be spread with ultrasound gel and then fitted into a sterile cover (a latex glove or a condom) also sprinkled with gel in order to aid ultrasound transmission and to lubricate the vaginal walls. Air bubbles should not be left between the transducer and the cover because they prevent ultrasound propagation. Should the condom break, and always at the end of each examination, the transducer should be sterilized and disinfected by bathing it in 2–3% glutaraldehyde and rinsed in sterile water.

The operator should start by scanning along the axial planes to obtain transversal uterine corpus sections (Fig. 3.3); then the transducer should be rotated to the right about 90° in order to obtain sagittal uterine scans. In this way, the uterus is visualized from the cervix to the fundus. For optimal cervix visualization, the transducer can be drawn back slightly. To observe the adnexa, the transducer should then be moved towards the lateral fornices and angled laterally.

The decreased distance between the transducer and the structures being examined, the possibility of using high-frequency transducers and the lack of interference from bowel gas make it possible to obtain better anatomical detail. Furthermore, transvaginal transducers allow a detailed colour Doppler examination, which

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Fig. 3.3. Structures scanned by ultrasound during a pelvic transvaginal examination, on a sagittal scan
provides important functional information, either for monitoring physiological flow variations associated with ovulation or to recognize signs of malignant neo-angiogenesis and thus help characterize uterine or ovarian masses (Fig. 3.4). A major limitation of transvaginal scanning is the lack of a panoramic view, preventing adequate study of large masses and processes occupying space in the upper pelvis.

**Fig. 3.4.** Doppler techniques. Colour Doppler sagittal scan of the uterus, periovulatory phase (a). Pulsed Doppler scans of the intramyometrial uterine arteries ((b), transverse plane of the uterine corpus) and venules ((c), sagittal plane) and of the intraovarian arterial branches (d). Note the higher velocities and arterial resistance for the uterine branches (a) compared with the intraparenchymal ovarian branches (d).

### Normal findings

**Uterus**

*Anatomy and measurements*

The uterus is located in the middle pelvis, in the space between the bladder and the rectum. It is situated medially to the Fallopian tubes, over the vagina and below the bowel loops. It is cone-shaped, with the base at the top and the apex sunk in the vagina. A circular narrowing in its inferior portion divides the uterus into two: the superior part is the uterine corpus and the inferior one is the uterine cervix, which
is shorter and cylindrical. The boundary between the corpus and the cervix is called the isthmus, which is very marked in female children, decreases in prepuberal girls and almost disappears in pluriparous women.

The superior extremity, called the fundus, is the widest part of the uterus. It has a concave profile at paediatric ages, is straight in nulliparous women and is convex in pluriparous women. Laterally, it forms two angles from which the Fallopian tubes originate. The uterus measures 6–7 cm in length, 4 cm in width and 3 cm in thickness; these dimensions increase by 1–2 cm in pluriparous women. The dimensions of the uterine corpus and cervix change with age (Table 3.1). In children, the uterine cervix is more prominent than the corpus, representing about three fifths of the total uterine length. At puberty, the uterine corpus becomes larger and longer; and in adult women it is longer than the cervix. In pluriparous women, the corpus is even larger, and its length represents about three fifths of the total. After menopause, the uterus becomes atrophic, with maximum volumetric reduction in the first 10 years.

<table>
<thead>
<tr>
<th>Age</th>
<th>Length (cm)</th>
<th>Width (cm)</th>
<th>Thickness (cm)</th>
<th>Volume (ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prepuberty</td>
<td>1–3</td>
<td>0.5–1.0</td>
<td>0.5–1.0</td>
<td>10–20</td>
</tr>
<tr>
<td>Pluriparous women</td>
<td>8</td>
<td>4</td>
<td>5</td>
<td>60–80</td>
</tr>
<tr>
<td>Nulliparous women</td>
<td>6–8</td>
<td>3–4</td>
<td>3–4</td>
<td>30–40</td>
</tr>
<tr>
<td>Postmenopausal women</td>
<td>4–6</td>
<td>2–3</td>
<td>2–3</td>
<td>14–17</td>
</tr>
</tbody>
</table>

When the bladder is empty, the uterus and vagina are oriented at an angle of about 90° (version angle); the uterine corpus is flexed towards the cervix at a variable angle of 140–170° (flexion angle), as seen by transvaginal scanning. When the bladder is filled (an indispensable condition for a transabdominal ultrasound scan), the uterus is pushed back, and the version and flexion angles increase (Fig. 3.5). In many women, the uterus tilts to the right or left but usually the right.
Structural features

The uterus is composed of three superimposed layers: the peritoneal serosa, the muscular layer, called the myometrium, which represents almost the entire uterine wall, and the mucosal layer, or endometrium.

The myometrium is composed of three layers, which can be distinguished by ultrasound:

- external, somewhat less echogenic than the intermediate layer, from which it is separated by arcuate vessels;
- intermediate, the thickest layer, with a homogeneous echo pattern and low-to-moderate echogenicity;
- internal, compact and hypovascular, hypoechoic and surrounds the relatively echoic endometrium (subendometrial halo).

Altogether, the uterus has an intermediate homogeneous echo pattern; in some cases, small ectatic vessels are visible in the most external myometrium. In older women, minute hyperechoic spots with a circumferential disposition are sometimes identifiable, representing parietal arteriolar calcifications. Within the uterine cervix,
small anechoic sub-centimetric formations, called Naboth cysts, can often be seen, which are due to occlusion and stretching of cervical glands by their secretion.

The endometrium looks like a central line with varied echogenicity and appearance, depending on the phase of the menstrual cycle (Table 3.2). The endometrium undergoes large changes in thickness and echogenicity due to the serum levels of estrogen and progesterone, which are detectable on either transabdominal or transvaginal scanning, which is the best technique for studying the uterus and adnexa. The cervical canal appears as an echoic linear stripe, and its aspect and thickening do not undergo significant variation during the menstrual cycle.

<table>
<thead>
<tr>
<th>Table 3.2. Endometrial thickness and ultrasound pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td>Menstrual phase</td>
</tr>
<tr>
<td>Proliferative phase</td>
</tr>
<tr>
<td>Periovulatory phase</td>
</tr>
<tr>
<td>Secretory phase</td>
</tr>
<tr>
<td>Postmenopause</td>
</tr>
<tr>
<td>Postmenopause with hormonal therapy</td>
</tr>
</tbody>
</table>

In the menstrual phase, the endometrium is extremely thin, formed from only the basal layer, and appears as a hyperechoic line, due to the interface between the anterior and posterior uterine walls. In the proliferative phase, the endometrium becomes progressively thicker and shows three concentric layers, consisting from the centre to the exterior of a central hyperechoic stripe due to the interface of the two endometrial surfaces, a hypoechoic intermediate layer due to the physiologically thickened functional stratum and an external echoic layer, which represents the basal stratum. Peripherally, there is a thin hypoechoic subendometrial halo, corresponding to the inner, less vascularized part of the myometrium. In the secretory phase, the endometrium appears homogeneously hyperechoic, because of vascular changes and glandular hyperplasia (Fig. 3.6).

The endometrial thickness is about 5 mm in the early proliferative phase and reaches 10–12 mm in the ovulatory phase. After menopause, the endometrium becomes atrophic and appears as a thin echoic stripe (maximum thickness, 3–4 mm) (Fig. 3.6). Only scant fluid is sometimes found within the uterine cavity, due to transitory staunching of secretion; it has no pathological significance. The endometrial thickness at menopause is used to classify benign and malignant diseases: a value of 5 mm is commonly accepted as the threshold, under which it is possible to exclude a tumoural pathology. For women of postmenopausal age who take hormonal therapy, varying patterns of endometrial thickening are seen, related to the type and phase of the hormonal treatment. In these women, an endometrial thickness > 5 mm is still acceptable.
Ovaries

Anatomy and measurements

The ovaries are ellipsoid and are located in most cases in the superior-lateral part of the retrouterine hollow. The ovaries juxtapose the lateral walls of the pelvis in Waldeyer fossae, delimited in the back by epigastric vessels and the ureter, in the front by the insertion of the large ligament and in the upper part by the external iliac vessels. The position of the ovaries is, however, often asymmetric, and, in spite of numerous connective ligaments, they are very mobile.

The best, most careful dimensional evaluation of the ovary is by volume calculation, by applying the ellipsoid formula: length × width × thickness / 2. The ovarian volume is relatively stable until 5 years of age, when progressive proportional growth is seen. In adult women, the ovary generally measures 3 × 2 × 1 cm. The ovarian volume varies from 2–3 ml in children to 4–5 ml in adolescents and 6–8 ml in adults. At menopause, the mean volume is reduced to about 3.7 ml, and the ovaries are difficult to see, even on transvaginal examination.

Fig. 3.6. Changes in endometrial thickness with phases of the menstrual cycle and with age. (a) Early proliferative phase. (b) Late proliferative phase. (c) Secretory phase (cursors: endometrium). (d) Postmenopausal atrophic endometrium
Structural features

The ovary has two morphologically and structurally defined areas: the medulla, which spreads from the hilum to the centre, and the cortex, which surrounds the medulla. The medulla is made up of vessels in connective and muscular tissue; sonographically, it is somewhat more echoic than the myometrium. The cortex contains the essential ovarian elements, the follicles, which differ in number and dimensions depending on the woman’s age and the phase of the menstrual cycle. On ultrasound scanning, the follicles appear as roundish or oval anechoic structures, with well-defined borders. At paediatric ages, small follicles, measuring a few millimetres, can already be seen.

In adult women, the ovary is an extremely dynamic structure, and its ultrasound pattern varies according to the phase of the cycle. In the estrogenic phase, some follicles begin to develop (Fig. 3.7), but only one will mature completely (the dominant follicle). This follicle (Fig. 3.8) grows linearly, from the 5th or 6th day until ovulation, at a mean growth of 2–3 mm a day.

Fig. 3.7. Multifollicular ovary

Fig. 3.8. Dominant follicle. Transvaginal scan of the ovary at day 13 of the menstrual cycle shows the dominant follicle as a rounded echo-free structure (about 15 mm in size).
The mean diameter of the dominant follicle at ovulation is 20 mm, with a range of 17–26 mm; this wide range limits the use of follicular diameter as a predictor of ovulation. After the follicle bursts and releases the oocyte, the residual cavity becomes virtual and partially occupied by haematic material, which is then replaced by proliferating thecal cells, thus forming the corpus luteum. The ultrasound morphology of the corpus luteum is variable; typically, it appears as a small cystic formation, with irregular borders and internal echoes due to its haematic contents, often with prominent peripheral vascular signals and typical low-resistance flow (Fig. 3.9). In some cases, the follicle collapses and the corpus luteum is not identifiable. In other cases, a larger, sometimes haemorrhagic luteal cyst forms but tends to resolve in subsequent cycles.

Fig. 3.9. Corpus luteum. Transvaginal scans show an inhomogeneous area within the left ovary (a), with peripheral vascular signals on power Doppler (b) and low-resistance flow on pulsed Doppler (c)

The ovarian structure and modification of the follicles during the menstrual cycle can be seen better with transvaginal transducers, although they can also be identified by transabdominal scanning. Appraisal of modifications of ovarian structure and follicles during the menstrual cycle is an integral part of gynaecological echographic examinations, because they give useful functional information.
During menopause, the follicles are no longer identifiable and the ovaries show a hypoechoic, uniform structure sonographically (Fig. 3.10); in 14.8% of cases, benign, simple cysts (< 5 cm) can be seen.

Ovarian dysfunction: polycystic ovary syndrome

Polycystic ovary syndrome is the commonest endocrine disorder in women of reproductive age. There is no internationally accepted definition of this syndrome, and the criteria for its diagnosis have yet to be standardized. The symptoms are heterogeneous and highly variable. In its classic form, polycystic ovary syndrome is characterized by chronic anovulation, irregular menses and hyperandrogenism, which may be associated with hirsutism, acne, seborrhoea and obesity. Polycystic ovary syndrome is considered to be present when at least two of the following are present:

- oligo-amenorrhoea or anovulation;
- clinical or biochemical signs of hyperandrogenism, in particular a ratio of luteinizing hormone: follicle-stimulating hormone > 2.5, increased levels of testosterone or an elevated free androgen index;
- sonographic evidence of polycystic ovaries.

Pelvic ultrasound can make a valuable contribution to the diagnosis of polycystic ovary syndrome, but it must be supplemented with a careful history and laboratory work-up. The ultrasound features of a polycystic ovary are (Fig. 3.11):

- multiple (≥ 8), small (mean diameter, 2–8 mm) follicles within the ovarian cortex;
- increased stromal density in the central cortex;
increased ovarian volume (≥ 10 ml), calculated according to the formula: 
\[ \pi \times \frac{1}{6} \times A \times B \times C \], where A, B and C represent the longitudinal, anteroposterior and transverse diameters of the ovary, respectively.

Abnormal ultrasound findings are generally present in both ovaries. Recent reports suggest that the transvaginal approach is preferable to the transabdominal, when possible.

A differential diagnosis of polycystic ovary syndrome includes multifollicular ovaries, which are associated with the presence of normal or mildly enlarged ovaries containing multiple follicles (Fig. 3.6). The follicles are distributed throughout the ovarian section and are often larger than those in polycystic ovary syndrome. Unlike polycystic ovary syndrome, multifollicular ovaries are not associated with accentuation of the stromal component.

Addition of colour Doppler greatly improves the diagnostic efficacy of transvaginal ultrasound, as it provides morphological and pathophysiological data on the flow dynamics in ovarian and pelvic vessels. In polycystic ovary syndrome, the pulsatility index of the uterine arteries is increased and vascularization is reduced, with a decrease in the resistivity index of the intraovarian arterioles, indicative of enhanced stromal vascularization.

Encouraging results have been obtained with three-dimensional transvaginal ultrasound, which provides more reliable estimates of organ volumes and blood flow and, most importantly, leads to standardization of ultrasound examinations. Introduction of this advanced technique has improved the precision and reproducibility of ovarian measurements. The stromal volume can be calculated as the difference between the total ovarian volume and the total follicle volume. This approach also allows quantitative assessment of the ovarian vasculature by quantification of Doppler signals.
Uterine disorders

Congenital abnormalities

Congenital uterine abnormalities due to developmental defects of the Müllerian ducts are clinically important because they are associated with higher rates of spontaneous abortion, premature birth and abnormal fetal position at delivery. Estimates of their frequency vary widely, but the overall data indicate a prevalence of about 1% in the general population and > 3% in women with recurrent pregnancy loss. As the urinary and genital systems arise from common embryonic structures, abnormal differentiation of the uterovaginal canal is frequently associated with renal anomalies (e.g. unilateral renal agenesis and crossed renal ectopy). The ovaries develop separately and are therefore not usually involved.

The most widely accepted classification (American Fertility Society, 1988) separates Müllerian duct anomalies into classes with similar clinical features, but complex and associated obstructive anomalies may also occur. Incomplete or absent fusion and resorption of the Müllerian ducts result in a didelphys, bicornuate or septate uterus. Septate uterus is the commonest Müllerian duct anomaly (approximately 55%) and is associated with the highest rate of recurrent spontaneous abortions. On ultrasound, the external configuration of the uterus is almost normal, but the endometrial stripe near the fundus is partially split into two symmetrical endometrial complexes by a septum isoechoic to the myometrium; the longitudinal extension and degree of vascularity of the septum can be assessed by ultrasound (Fig. 3.12). In the bicornuate uterus, there is incomplete fusion at the level of the fundus, with an intervening fundal cleft of variable length; two divergent uterine horns are fused caudally, with two endometrial cavities communicating inferiorly or two separate endometrial cavities and cervical canals. In uterus didelphys, two separate, divergent uteri can be seen, each with its endometrial cavity and cervix. There is only partial fusion at the level of the cervixes and no communication between the two endometrial cavities.

Abnormal development of the Müllerian ducts before fusion results in agenesis or hypoplasia of the uterus and vagina, such as in Mayer-Rokitansky-Küster-Hauser syndrome (vaginal agenesis associated with uterine agenesis or an obstructed or rudimentary uterus). A unicornuate uterus results when only one Müllerian duct develops normally (approximately 20%).

The features of different Müllerian duct anomalies may be further complicated by obstruction due to vaginal agenesis or transverse vaginal septa. If functional endometrial tissue is present, the condition may be suspected at menarche, with cyclic pelvic pain and a pelvic mass due to progressive accumulation of menstrual blood with or without primary amenorrhoea, depending on whether there are concurrent duplicate anomalies. On ultrasound the vagina and the endometrial cavity are distended by fluid and usually appear as a cystic mass; the contents may be hypoechoic, the low-level echoes being due to retained menstrual blood (haematocolpos or haematometrocolpos), or anechoic, due to mucous secretions in neonates (hydrocolpos or hydrometrocolpos) (Fig. 3.13).
In order to evaluate congenital anomalies, the ultrasound examination should be performed during the secretory phase of the menstrual cycle (Fig. 3.12), as the echogenic endometrium is more easily recognized at this time. The purpose of the ultrasound examination should be to evaluate the morphology not only of the uterine cavity but of the external fundal contour (convex, flat, with an indentation or cleft). This information is crucial, as therapeutic modalities vary widely depending on the underlying anomaly. Three-dimensional ultrasound, which allows coronal reconstruction and better delineation of the external contour and volume of the uterus, is the most effective for demonstrating such anomalies, with higher sensitivity and specificity than conventional ultrasound. In complex anomalies, however, ultrasound may not allow adequate analysis of the uterovaginal anatomy. Magnetic resonance
imaging (MRI), although more expensive than ultrasound, is reported to be the most accurate for evaluating Müllerian duct anomalies. When uterine anomalies are detected, the ultrasound examination should be extended to the kidneys because of the frequent association with renal anomalies (reported in up to 31% of cases).

**Benign endometrial disease**

In diagnostic work-up of endometrial disease, the examiner must remember that the appearance of the endometrium is determined by many factors (the woman’s age, the phase of the menstrual cycle, hormonal replacement or tamoxifen therapy), all of which must be taken into account with the clinical history and the findings of the physical examination. The main ultrasound sign of disease is increased endometrial thickness that is not consistent with age or menstrual phase. Increased thickness is, however, a nonspecific finding, which can be seen in several benign and malignant conditions. In order to make a correct diagnosis, the ultrasound evaluation must therefore include other features, such as echo texture, the endometrial–myometrial interface and the degree of vascular signals. Sonohysterography, in which the endometrial cavity is distended with saline, reliably distinguishes focal from diffuse abnormalities and characterization of most endometrial lesions.

**Endometritis**

Endometritis is often an early stage of pelvic inflammatory disease (when infection from the lower genital tract extends upwards to the Fallopian tubes and peritoneal cavity), or it may follow puerperal or post-abortion complications or insults due to instrumentation or intrauterine contraceptive devices. The endometrium may appear almost normal in mild cases, diffusely hypoechoic or thickened and heterogeneous. Prominent vessels may be seen within the myometrium, secondary to hyperaemia. Scant intracavitary collections of fluid may simulate an intrauterine abortion or a pseudogestational sac; larger echogenic fluid collections are a sign of more severe disease (pyometra, abscess). Intrauterine air pockets (due to gas-producing bacteria) are a more specific but rare sign of infection (Fig. 3.14). In genital tuberculosis, the endometrium is affected in 60–90% of cases, and the uterus may be enlarged due to filling and expansion of the endometrial cavity by caseous material.
Endometrial hyperplasia
Diffuse proliferation of endometrial stroma and glands is defined as hyperplasia. It is prevalent in women around menopause and in conditions of unbalanced estrogenic stimulation. Because of the increase in glandular mass, hyperplasia is most often seen as a diffuse, smooth thickening of the whole endometrium (Fig. 3.15), similar to that seen during the secretory phase. The endometrial thickness must thus always be compared with normal values and the appearance expected for the menstrual phase or age of the woman. Smaller sonolucent areas in the thickened endometrium, or focal thickening, although less common, are occasionally seen.

Fig. 3.15. Endometrial hyperplasia. Sagittal transvaginal scan in a postmenopausal woman reveals a diffusely thickened endometrium, which is symmetrical and homogeneous. The separation between the endometrium and myometrium is clear.
The separation between the endometrium and myometrium is always present. An endometrium with an inhomogeneous texture is probably due to other abnormalities (large polyps, submucosal fibroids, cancer) and is best assessed by sonohysterography or biopsy if there is a clinical suspicion of malignancy.

**Endometrial polyps**

Endometrial polyps are a common cause of abnormal vaginal bleeding, although they may be asymptomatic and found incidentally. They are most frequent in perimenopausal women or in women receiving tamoxifen as adjunct therapy for breast cancer. Most polyps are echogenic and are therefore best identified during the estrogenic phase of the menstrual cycle, appearing as small, well-defined, homogeneous lesions surrounded by the hypoechoic proliferative endometrium (Fig. 3.16). Polyps may also be isoechoic and blend into the surrounding endometrium, resulting in nonspecific endometrial thickening with preservation of the endometrial–myometrial interface. Larger or complicated polyps (due to hemorrhage, infarction or inflammation) may be more heterogeneous or show tiny cystic spaces (Fig. 3.17).

Colour Doppler can usually demonstrate the feeding vessels in the stalk of the polyp, thus helping to differentiate polyps from hyperplasia (Fig. 3.18). Sonohysterography allows easy, reliable diagnosis of polyps, as they appear as smooth or irregular, broad-based or pedunculated masses, well outlined by the saline solution instilled in the uterine cavity.

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**Fig. 3.16.** Endometrial polyps in a premenopausal asymptomatic woman. Transvaginal sagittal scan of the uterus in the estrogenic phase of the menstrual cycle shows two smooth rounded masses, slightly echogenic compared with the surrounding hypoechoic proliferative endometrium.
Tamoxifen therapy, intrauterine fluid collections and adhesions

Tamoxifen, widely used in former years as adjunct therapy in breast cancer patients, has a weak estrogenic effect on the endometrium, increasing the prevalence of endometrial hyperplasia, polyps and carcinoma. In women under tamoxifen therapy, the endometrium may appear thickened and irregular and show multiple cystic spaces (so-called cystic atrophy) in a subendometrial location, as shown by sonohysterography.
During the menstrual phase and in postmenopausal women, the finding of scant fluid within the uterine cavity is not rare and may be considered normal. Larger fluid collections are abnormal, as they are often associated with uterine malignancies. Congenital obstructive malformations of the uterus and vagina (such as cervical atresia, vaginal septa and imperforate hymen) in prepubertal children and even in neonates may lead to the accumulation of large fluid volumes within the endometrial canal or the vagina (hydro- or haematometrocolpos) (Fig. 3.13). The fluid accumulated within the uterine cavity may be echo-free (mucin) or hypo- to hyperechoic (serum or blood).

Endometrial adhesions, or synechiae, may develop as a result of endometrial injury (due to dilatation and curettage, caesarean delivery, evacuation of a hydatidi-form mole or pelvic tuberculosis) and may be associated with infertility, recurrent pregnancy loss or amenorrhoea. Ultrasound examination requires fluid distension of the endometrial cavity by means of sonohysterography, which can demonstrate adhesions as echogenic bands crossing the uterine cavity; they may be mobile and thin, thick and broad-based or, occasionally, completely obliterating the endometrial cavity.

**Benign myometrial disease**

**Fibroids**

Uterine leiomyomas (also referred to as myomas or fibroids) are common benign soft-tissue tumours, frequently multiple, composed of smooth muscle and connective tissue, affecting nearly one fourth of women of reproductive age. Depending on their size and location, the symptoms include abnormal uterine bleeding, dysmenorrhoea, mass effect (bladder and rectal pressure) and pelvic and back pain. Owing to their estrogen sensitivity, fibroids tend to increase in size and number with age up to menopause, sometimes with periods of growth acceleration (e.g. in early pregnancy) or, conversely, involution (in menopause or puerperium) and may therefore undergo necrosis and degenerative changes (haemorrhage, infarction, calcification, fatty degeneration). They commonly appear as rounded, hypoechogenic, solid masses, but may be heterogeneous or also hyperechoic, and show acoustic shadowing (due to calcifications) or cystic areas (Fig. 3.17, Fig. 3.19, Fig. 3.20, Fig. 3.21). Transvaginal examination may show whorls, with multiple discrete shadows originating from within the mass (recurrent shadowing), and this typical pattern can be useful in cases of diagnostic ambiguity (Fig. 3.19, Fig. 3.22). Colour Doppler can show the peripheral blood supply of fibroids, the vessels mainly coursing around the fibroid with scant central flow (Fig. 3.22). In large fibroids with necrotic or degenerative changes, increased blood flow and an inhomogeneous texture may even mimic uterine sarcomas, on both grey-scale and colour Doppler.
Depending on their location, fibroids are referred to as **intramural** when located within the myometrium (Fig. 3.21), **subserosal** when they are external and distort the uterine contour (Fig. 3.19), **submucosal** when they distort or extend into the endometrial cavity (Fig. 3.20) or **pedunculated** in a serosal or submucous location. Exophytic pedunculated fibroids can be misdiagnosed as they can mimic adnexal and other pelvic disorders. Submucosal fibroids may distort the uterine cavity or be almost entirely endoluminal. The degree of protrusion of the fibroid into the endometrial cavity is important information for surgical management and is best determined by sonohysterography.

**Fig. 3.19.** Fibroids. Transabdominal (a) and transvaginal (b) sagittal scans in a premenopausal woman show increased volume of the uterus and irregular appearance of its external configuration due to multiple hypo- and isoechoic fibroids, some with acoustic shadowing. Because of impaired transmission and poor visualization of endometrial echoes, the exact number, size and location of fibroids are difficult to determine accurately.

**Fig. 3.20.** Submucosal fibroid. Axial transvaginal sonogram shows a hyperechoic inhomogeneous fibroid (cursors) with minimal distortion on the overlying endometrium.
Although fibroids are usually easily identified and diagnosed by ultrasound, technical limitations may impair the examination. MRI can be helpful, as it allows accurate assessment of the total number and location of fibroids and the presence of concurrent adenomyosis or other uterine or ovarian disorders.

**Adenomyosis**

*Uterine adenomyosis* is defined as the presence of endometrial glands and stroma in the myometrium beneath the endometrial–myometrial junction, with accompanying smooth muscle hyperplasia. With diffuse involvement, the uterus is enlarged, with thickening and asymmetry of the walls, pseudo-widening of the endometrium, poor definition or shaggy appearance of the endo–myometrial junction and small
cyst-like areas of fluid (usually < 5 mm) within the myometrium (Fig. 3.23). With focal involvement, the myometrium is thickened and heterogeneous, with echogenic linear striations, poorly defined echogenic nodules or circumscribed hypoechoic nodules resembling a fibroid but with ill-defined margins and minimal mass effect. In contrast to fibroids, the adenomyosis nodules have blood flow (raindrop appearance).

Notwithstanding these many signs, the ultrasound detection of adenomyosis, and especially differential diagnosis from fibroids, can be difficult, so that this condition is frequently overlooked, especially when uterine fibroids coexist. As the therapeutic options differ, equivocal ultrasound findings (fibroids or adenomyosis) can be resolved by MRI to assess both adenomyosis and pelvic endometriosis with greater accuracy.
Neoplasms

Atypical vaginal bleeding (i.e. between menstrual cycles or in the postmenopausal period) is of great concern as it is the common presenting sign of endometrial and cervical cancers. Although the causes of bleeding are usually benign (postmenopausal atrophy, endometrial polyps and hyperplasia, submucosal fibroids), about 10% of all postmenopausal bleeding is due to endometrial carcinoma. In postmenopausal women, the ultrasound finding of an endometrium measuring ≤5 mm (double-layer thickness), which is smooth and homogeneous in the absence of any focal thickening, is consistent with atrophy and excludes any significant disease, such as endometrial cancer. The criteria may vary if the woman is receiving hormonal replacement therapy, as the expected thickness of the endometrium is increased. In the presence of postmenopausal bleeding, any abnormal increase in thickness or focal structural abnormality of the endometrium should be investigated further, possibly by sonohysterography or hysteroscopy, as blind endometrial sampling can yield false-negative results if the abnormality is focal and not sampled.

Endometrial carcinoma

Endometrial cancer is the commonest gynaecological malignancy (about 6% of all cancers in women). Abnormal or postmenopausal bleeding is the earliest, most frequent presenting symptom. The main ultrasound sign is nonspecific thickening of the endometrium, which is usually diffuse but can be polypoid in early cases. Endometrial tumours are usually more heterogeneous than hyperplasia or polyps and appear as a marked irregular or mass-like thickening, of varying echogenicity, and are often difficult to distinguish from the myometrium because of irregularity or focal effacement of the endometrial–myometrial border (Fig. 3.24, Fig. 3.25, Fig. 3.26). Corpusculated fluid may accumulate in the endometrial cavity due to cervical stenosis.

The tumour tissue may show abnormal flow signals on colour and power Doppler imaging, indicating high-velocity, low-resistance arterial flow (Fig. 3.24, Fig. 3.25, Fig. 3.26).

Treatment and prognosis are based mainly on tumour extent (depth of myometrial invasion, cervical and nodal involvement), as well as individual and histological factors. An indistinct or disrupted endometrial–myometrial interface is a sign of myometrial invasion. The depth of invasion (deepest point reached by the tumour inside the myometrium wall) is rated as superficial if only the inner half of the myometrium is involved or deep if it involves the outer half of the myometrium and beyond, also depending on whether the residual uterine wall is more or less than 1 cm (Fig. 3.24). Technical limitations (acoustic shadowing from fibroids, adenomyosis, uterine size, thinning of uterine walls due to distension from a clot, fluid or polypoid tumour) may reduce the accuracy of ultrasound.

Contrast-enhanced MRI is currently seen as the most reliable technique for evaluating myometrial invasion, with significantly better performance than non-enhanced MRI, ultrasound and CT. Cervical invasion is difficult to assess with
Fig. 3.24. Endometrial carcinoma. Transabdominal coronal (a) and sagittal (b) scans show a diffusely enlarged uterus and complete disruption of the endometrial–myometrial junction by irregular echogenic tissue, almost reaching the serosa posteriorly (b). (c) On Doppler examination, abnormal endometrial vessels and low-impedance arterial flow are seen.

Fig. 3.25. Endometrial carcinoma in an 80-year-old woman. Transabdominal sagittal scans show (a) a markedly enlarged, hypoechoic endometrial stripe (cursors) and increased uterine size. On colour Doppler imaging (b), note increased blood flow and multiple vessels peripheral to and within the tumour.
ultrasound or computed tomography, whereas it is accurately depicted by MRI. Paraoaortic and pelvic lymphadenopathies are often not detected by sonography and are more reliably shown by MRI and CT.

The ultrasound features of endometrial cancer can be difficult to differentiate from endometrial hyperplasia and polyps. The thickness of the endometrium is often similar in benign and malignant conditions. Malignancy should be suspected in the presence of a very thick or irregular endometrial stripe or when the endometrial–myometrial interface is disrupted. Contrast-enhanced MRI is considered the most reliable technique for evaluating myometrial invasion.

Cervical carcinoma
Cervical carcinoma is the commonest gynaecological malignancy in premenopausal women, spreading by direct local invasion or through the lymphatic system. The most significant prognostic factors are tumour size and the status of the para-aortic lymph nodes; staging variables include extension into the vagina, parametria or pelvic walls, invasion of the bladder or rectum and spread to distant organs. In early
stages, the diagnosis is clinical rather than by imaging techniques, which are necessary for correct staging of more advanced tumours.

On transabdominal sonography, the cervix may be diffusely enlarged by a hypo- or isoechoic mass, and the uterine cavity may be distended by fluid and debris (haematometra). On transvaginal or transrectal sonography, the tumour may appear as a hypoechoic or isoechoic (relative to normal uterine muscle and the cervical stroma), poorly defined lesion within an enlarged cervix (Fig. 3.27, Fig. 3.28), asymmetrical and prolonging laterally when parametrial invasion occurs, or disrupting the vesical or rectal wall (Fig. 3.29, Fig. 3.30). Transvaginal or transrectal sonography can be used to evaluate the size of the cervix but not consistently the size of the tumour, because of poor discrimination between normal cervical stroma and tumour tissue.

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Fig. 3.27. Cervical carcinoma, stage I. Transvaginal sagittal scan shows a superficial tumour of the cervix as an ill-defined, hypoechoic area ( cursors) effacing the central linear echo of the cervical canal

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Fig. 3.28. Cervical carcinoma, stage II. Transrectal sagittal scan shows enlargement of the cervix ( cursors) by the tumour, with effacement of the cervical canal
Myometrial and vaginal involvement can be detected, although not consistently, by an upwards extension of the cervical lesion or by irregular thickening of the anterior or posterior vaginal wall, respectively, continuous with the cervical lesion. Increased intratumoral blood flow may be found on colour Doppler in larger lesions; this finding appears to be related to the aggressiveness of the tumour and the likelihood of nodal invasion.

The limitations of transrectal and, to a lesser extent, transvaginal scans are that it is difficult to evaluate tumour extension to the pelvic wall or to scan large tumours when the leading edge of the tumour is beyond the range of the probe. Bladder and rectal invasion are accurately detected by transvaginal or transrectal sonography as the loss of intervening fat planes and by hypoechoic thickening and loss of the normal layered pattern of the vesical and rectal walls (Fig. 3.29, Fig. 3.30). Transabdominal sonography can readily detect obstruction of the urinary tract (due to parametrial invasion with ureteral obstruction), gross bladder invasion and liver metastases in advanced disease, but has a limited role in identifying enlarged pelvic or para-aortic lymph nodes, which are more reliably detected by CT and MRI. MRI appears to be the single most accurate technique for local staging of cervical carcinoma.

Sonography can be useful in local staging of cervical cancer, especially with a transvaginal or transrectal technique, but has limitations, especially in assessing lymph node involvement and extension to the pelvic walls. Accurate local staging is best accomplished with MRI, whereas both CT and MRI can be used to assess extrapelvic disease.

Fig. 3.29. Cervical carcinoma, stage IVA. Transabdominal sagittal and transverse scans show a bulky hypoechoic lesion replacing the uterine cervix and body, with associated fluid collection within the upper uterine cavity. The tumour mass disrupts the uterovesical septum and invades the bladder.
Sarcoma and chorioncarcinoma

Leiomyosarcoma is an aggressive tumour, often diagnosed only histologically after hysterectomy or clinically suspected by its rapid growth, metrorrhagia and pelvic pain. Although signs of necrosis and markedly increased intratumoral blood flow have been described on sonography and Doppler, leiomyosarcoma is difficult to distinguish from leiomyoma, unless its rapid growth raises clinical suspicion or there is evidence of local invasion or metastasis.

In chorioncarcinoma (gestational trophoblastic neoplasia), multiple hypoechoic areas surrounded by irregular echogenic areas and abundant intramyometrial vascularity with low resistance flow may be seen on grey-scale and colour Doppler sonography.

Recurrent disease

Local recurrence of gynaecological malignancies on the vaginal cuff or within the central pelvis is relatively frequent in women who have undergone radical hysterectomy. Larger recurrences can be detected even on transabdominal scans as space-occupying lesions, centrally located and continuous with the vaginal cuff. Transrectal and transvaginal sonography allow more detailed visualization of the vaginal cuff and central pelvis and are therefore useful for accurate detection or exclusion of tumour recurrence. Focal enlargement, structural abnormalities or true masses, usually with increased vascularity, can be seen in cases of early and more advanced recurrences (Fig. 3.31, Fig. 3.32); possible infiltration of the parametrial tissues or of the recto-vaginal or vesico-vaginal septa can also be assessed.
Fig. 3.31. Vaginal recurrence of endometrial carcinoma. (a) Transabdominal examination shows a solid mass continuous with the vagina. (b) Follow-up transrectal sagittal scan after radiotherapy shows a reduction in the size of the lesion (R); the recto-vaginal septum and rectal wall are normal. VA, vagina; BL, bladder

Fig. 3.32. Vaginal recurrence of cervical carcinoma. Transrectal sagittal scans (a), along the right and (b), along the left aspect of the vagina) show a vaginal cuff of normal size; however, a small inhomogeneous hypoechoic area with irregular borders (cursors) is seen in its right portion, due to a small recurrence. Note normal rectal wall and recto-vaginal septum
Adnexal lesions
Ovarian masses: the importance of ultrasound

Ultrasound examination is clearly the most informative means of studying ovarian neoformations, i.e. structures inconsistent with the normal physiology of this organ. These should be distinguished from the numerous functional formations detected in the ovarian parenchyma during the menstrual cycle, such as follicles, corpora lutea and luteal cysts, which are not classified as pathological formations.

Ultrasound allows analysis in vivo of all the characteristics evaluated by surgeons and anatomical pathologists. Both anatomical pathologists and ultrasound operators can suspect a diagnosis on the basis of the morphological characteristics of a lesion, such as its complexity, the presence of solid portions and irregularity. Ultrasound examination also allows evaluation of additional parameters, such as vascularization, the relation of the lesion to nearby organs and tenderness on pressure. These characteristics make ultrasound an accurate diagnostic tool for discriminating between malignant and benign ovarian masses and, in many cases, for making a specific diagnosis.

Classification systems

Differentiation of ovarian masses into benign and malignant masses is based on many morphological parameters. Transvaginal ultrasound investigation of any adnexal mass (or either transabdominal ultrasound for larger masses) provides information on its location in the pelvis, its laterality and its relation with the ovarian parenchyma and with the adjacent organs. It also allows a quantitative assessment of the size of both ovaries and the lesions, measured by taking the three largest diameters in two perpendicular planes (Fig. 3.33).

Transvaginal ultrasound investigation provides information on the morphology of the mass, classified into unilocular, multilocular, unilocular–solid, multilocular–solid, solid or unclassifiable (Table 3.3).

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Fig. 3.33. Measurement of (a) the ovary and (b) an ovarian cyst from the three largest diameters in two perpendicular planes
Information can also be obtained if a septum or multiple septa are present. (Fig. 3.34) shows a complete (thin strand of tissue running across the cyst cavity from one internal surface to the contralateral side) and an incomplete septum (which is not complete in some scanning planes). The thickness is measured where it appears to be at its widest.

**Solid papillary projections** are any solid projections into the cyst cavity from the cyst wall with a height ≥ 3 mm (smooth or irregular). The height and base of the largest projection are measured. The number of separate papillary projections and whether blood flow can be detected are also recorded (Fig. 3.35).
Fig. 3.34. Septa. (a) Complete septum. (b) Measurement of a septum. (c) Incomplete septum

Fig. 3.35. (a), (b) Solid papillary projection
The **cystic contents** can be anechoic (black), have homogeneous low-level echogenicity (as seen in mucinous tumours or an appearance similar to amniotic fluid), have a ground-glass appearance (homogeneously dispersed echogenic cystic contents, as seen in endometriotic cysts), be haemorrhagic (internal thread-like structures, representing fibrin strands; star-shaped, cobweb-like, jelly-like) or mixed (as often seen in teratomas) (Fig. 3.36).

**Acoustic shadows** are seen as a loss of acoustic echo behind a sound-absorbing structure (Fig. 3.37).

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Fig. 3.36. Cystic contents. (a) Anechoic. (b) Low-level. (c) Ground glass. (d) Haemorrhagic. (e) Mixed
A subjective, semiquantitative assessment of vascularization (within a septum or papillary projections) can be made by means of colour Doppler analysis and given a colour score from 1 (absence of flow) to 4 (hypervascularization).

Ultrasound investigation can also demonstrate fluid in the pouch of Douglas or ascites (fluid outside the pouch of Douglas).

Clinical data (family history of gynaecological neoplasms, age, parity, menopausal state, hormonal therapy, pain) and serological data (presence of CA-125 protein) are then linked to the ultrasound findings. The International Ovarian Tumor Analysis Group analysed all the parameters described above to identify significant differences between benign and malignant masses. On the basis of the morphology of the lesion, the prevalence of malignancy was 0.6% in unilocular neoformations, 10% in multilocular, 33% in solid–unilocular, 41% in solid–multilocular and 62% in solid formations. With logistic multivariate regressive analysis, the parameters that were significantly independent predictors of malignancy were: the woman’s age, a positive history of ovarian carcinoma, the diameter of the largest lesion, the diameter of the solid component, the presence of ascites, the presence of solid vascularized tissue, a completely solid aspect of the lesion and the colour score. Factors that indicated a reduced risk for malignancy were: cone shadow, pelvic pain during examination and hormonal therapy. The variables were used to elaborate a mathematical model to predict risk for malignancy. The applicability and accuracy of this model are being studied in centers that were not involved in its development, before it may be used to evaluate risk in the general population. The International Ovarian Tumor Analysis Group has also drawn up simple rules, which, if applicable, will predict whether an ovarian mass is benign or malignant (Table 3.4).
If one or more M rules apply in the absence of a B rule, the mass is classified as malignant; if one or more B rules apply in the absence of an M rule, the mass is classified as benign; if both M rules and B rules apply, the mass cannot be classified; if no rule applies, the mass cannot be classified. In the published study, the rules were applicable for 76% of the tumours, with a sensitivity of 95% and a specificity of 91%.

Specific diagnosis
Once detected, an ovarian lesion should be evaluated for the risk for malignancy, and the ultrasound examiner should express a specific diagnosis. It is therefore important to distinguish between physiological structures in the ovary (e.g. follicles and corpus luteum), abnormal but functional masses (e.g. due to ovarian hyperstimulation or a haemorrhagic corpus luteum) and clearly pathological structures.

Physiological structures and functional lesions
The follicles are recognized by ultrasound as anechoic rounded formations with a thin regular wall and a diameter ranging from a few to 18–20 mm (Fig. 3.38). The corpus luteum can assume various morphological aspects: it generally has a starry aspect due to deflation of the follicular wall after ovulation, with cobweb content. It may also contain haematic clots, which can be mistaken for papillary projections or solid components even by expert operators. A peripheral vascular ring is a typical finding on colour Doppler evaluation (Fig. 3.38).

### Table 3.4. Rules for predicting whether an ovarian mass is benign or malignant

<table>
<thead>
<tr>
<th>Classification</th>
<th>Characteristic</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Benign (B rules)</strong></td>
<td></td>
</tr>
<tr>
<td>B1</td>
<td>Unilocular</td>
</tr>
<tr>
<td>B2</td>
<td>Presence of solid components, of which the largest has a diameter &lt; 7 mm</td>
</tr>
<tr>
<td>B3</td>
<td>Presence of acoustic shadows</td>
</tr>
<tr>
<td>B4</td>
<td>Smooth multilocular tumour with the largest diameter &lt; 100 mm</td>
</tr>
<tr>
<td>B5</td>
<td>No blood flow (colour score, 1)</td>
</tr>
<tr>
<td><strong>Malignant (M rules)</strong></td>
<td></td>
</tr>
<tr>
<td>M1</td>
<td>Irregular solid tumour</td>
</tr>
<tr>
<td>M2</td>
<td>Presence of ascites</td>
</tr>
<tr>
<td>M3</td>
<td>At least four papillary structures</td>
</tr>
<tr>
<td>M4</td>
<td>Irregular multilocular solid tumour with the largest diameter ≥ 100 mm</td>
</tr>
<tr>
<td>M5</td>
<td>Very strong blood flow (colour score, 4)</td>
</tr>
</tbody>
</table>

Adapted from International Ovarian Tumor Analysis Group (2005)
Adnexal tumours

In order to diagnose ovarian neoformations accurately, it is important to review the structures that make up the ovarian parenchyma: the ovarian epithelium, from which all epithelial formations arise (benign, borderline and malignant); the germinal cells, from which teratoma cysts and the corresponding malignant neoformations arise; the stroma (fibroblast, vessels), in which the corresponding benign and malignant stromal tumours arise (ovarian fibromas, fibrothecomas and fibrosarcomas, granulosa-cell tumours, Sertoli-Leydig cell tumours). The ovary can also be the site of metastases originating from tumours in other organs.

Benign epithelial neoformations

Simple ovarian cysts

This group consists of unilocular cysts measuring up to 10–14 cm, which are anechoic, with sharp margins and no solid component. As smaller cysts are not distinguishable from ovarian follicles on ultrasound examination, in women of child-bearing age only those fluid images measuring > 3 cm are referred to as cysts. These lesions occur in 40% of cases of cystadenoma. This type of lesion should be followed up by ultrasound. Removal of these cysts is indicated when they appear as solid coins or when they are large.
Endometriotic cysts

Endometriotic ovarian cysts present highly typical ultrasound features and clinical symptoms, and diagnosis is usually easy. They are unilocular, with regular margins and a ground-glass or densely homogeneous content. Doppler examination reveals scant pericystic vascularization and no central vascularization. In some endometriotic cysts, septa are seen, which may be faintly vascularized. An ultrasound feature that is seen in 20% of cases, which is useful for differential diagnosis, is the presence of hyperechoic wall foci. Although they can be mistaken for papillae, they are accumulations of haemosiderin–fibrin or clots (Fig. 3.39).

Epithelial borderline neoformations and invasive carcinomas

Borderline ovarian tumours

Borderline ovarian tumours constitute 10–15% of all malignant neoplasms. They are considered to be one of the most difficult groups of masses to classify correctly, and numerous studies have been conducted to identify ultrasound characteristics that distinguish borderline ovarian tumours from primitive ovarian tumours.

Borderline ovarian tumours are characterized histologically as serous and mucinous and the latter as endocervical and intestinal type. On ultrasound examination, the morphological characteristics of mucinous endocervical borderline ovarian tumours are similar to those of serous tumours: both are frequently unilocular–solid lesions with papillary projections. On the contrary, the mucinous intestinal-type borderline ovarian tumors have different morphology: mucinous intestinal-type lesions are greater than endocervical-type lesions, and are frequently multilocular with regular septa and a large number of concamerations (Fig. 3.40).
Epithelial ovarian carcinomas

Early-stage borderline tumours and ovarian carcinomas have numerous ultrasound characteristics in common. The solid tissue of the neoplasm increases in proportion with degree of malignancy, from borderline to the various stages of ovarian carcinoma, and becomes progressively more echogenic, with more irregular borders. Borderline ovarian tumours and the first stages of ovarian carcinoma have a similar percentage of papilla formation, which is significantly higher in advanced cases, with a significantly lower percentage of solid neoformations.

Germinal ovarian tumours

Cystic teratoma

Cystic teratoma (dermoid) is a benign neoformation which originates from the three embryonic membranes, the ectoderm, the mesoderm and the endoderm. It is constituted mainly of sebaceous material and piliferous structures, often with teeth, bones and muscular tissue inside. On ultrasound, the lesions appear unilocular, with an inhomogeneous content or with horizontal hyperechoic stria, due to hair. The piliferous content sometimes concentrates inside the formation to form the Rokitansky
nucleus, which, on ultrasound, has the appearance of a hyperechoic, roundish formation (white ball); it should not be mistaken for solid parenchymal tissue. A prevalently cystic echo pattern is seen in 9–18% of dermoids (Fig. 3.41).

Fig. 3.41. Ultrasound features (a) and macroscopic aspect (b) of a dermoid cyst

Malignant germinal tumours
The rare malignant germinal tumours can be divided into dysgerminomas, yolk sac tumours and choriocarcinomas. Given the rarity of these neoplasms, there are no characteristic ultrasound markers; they are usually seen as large, multilocular, solid lesions, with rich vascularization.

Stromal tumours
Fibromas, fibrothecomas and Brenner tumours
Most stromal tumours are benign. Ovarian fibromas and fibrothecomas are often considered to be difficult to diagnose by ultrasound. Ovarian fibromas often have characteristic features that may suggest a diagnosis, such as a solid spherical or ovoidal structure and hypo- or anechoic stria arranged like a halo (stripy echogenicity). The ultrasound characteristics of fibrothecomas, however, are not well defined. They are solid, often with cystic concamations, but their inner structure is sometimes so inhomogeneous that it is difficult to differentiate them from malignant ovarian masses.

Granulosa-cell tumours and Sertoli-Leydig tumours
Stromal tumours also include neoplasms arising from the mesenchymal tissues, from granulosa cells and from Sertoli-Leydig cells. Granulosa-cell tumours and Sertoli-Leydig tumours are rare lesions, and few studies have been conducted on ultrasound markers. In a multicentre study, granulosa-cell tumours were reported to be large tumours (median largest diameter, 102 mm; range, 37–242 mm), with moderate or high colour content on colour Doppler examination (colour score 3 in 57%, 4 in
They appear as multilocular–solid in 52%, purely solid in 39%, unilocular–solid in 4% and multilocular in 4% of cases. Multilocular and multilocular–solid cysts typically contain large numbers of small locules (>10). The echogenicity of the cyst content is often mixed (38%) or low (44%). Papillary projections are found in 17% of cases.

**Metastatic ovarian tumours**

Ovarian masses are metastases in 4–5% of cases. Most originate from neoplasms in the intestinal tract or breast. Anatomopathologically, ovarian metastases may appear as bilateral lesions or as multiple solid nodules within the ovary, partly cystic or, less frequently, totally cystic lesions. Extensive areas of necrosis or haemorrhage are commonly seen inside these lesions. Krukenberg tumours are typically solid, with a lobulated external surface (Fig. 3.42).

The ultrasound characteristics of histologically diagnosed ovarian metastatic tumours in 67 women were examined in a multicentre study. Nearly all the tumours (93%) deriving from primary malignancies of the stomach, breast or uterus or from lymphoma were solid, while metastases deriving from primary malignancies of the colon or rectum, appendix and biliary tract were multilocular or multilocular–solid.

**Paraovarian cysts**

Paraovarian cysts constitute 5–20% of pathological adnexal findings; they develop from embryonic ducts (mesothelial, mesonephric or paramesonephric) and are located between the Fallopian tube and the ovary. On ultrasound examination, paraovarian cysts usually appear as unilocular formations, with regular margins, round or oval, near to but separated from the ovarian ipsilateral parenchyma. The median diameter is variable, ranging from 15 to 120 mm. The contents can be anechoic or
finely corpuscular; in a high percentage of cases, the interior wall is irregular, due to the presence of papillary projections. According to some authors, papillae may be observed in 33% of paraovarian cysts; a large number of projecting papillae may be related to a histopathological borderline diagnosis.

**Peritoneal pseudocysts**

Peritoneal pseudocysts (or pelvic inclusion cysts) are loculated fluid collections resulting from fluids entrapped by adhesion strands, formed in the course of an inflammatory process in the peritoneal cavity or as a consequence of surgery. At times, they are observed as cystic formations, oval or roundish, but more often appear as anechoic collections modelled on the pelvic wall outline. The ovarian parenchyma may appear to be suspended between the adhesions in a central or peripheral region of the cyst. The cystic content can be anechoic or finely corpuscular, and the cyst may contain septa or papillary projections. Septa are present in about 80% of cases; they are often mobile when pressure is exerted by the endovaginal probe, producing the typical flapping sail movement.

**Fallopian tubes**

**Normal Fallopian tube**

The Fallopian tubes vary in length between 7 and 12 cm. Both tubes are situated in the superior free margin of the large ligament, covered by peritoneum. The different anatomical parts of the salpinges can be distinguished as the interstitial, the isthmic, the infundibular and the ampullar (Fig. 3.43).

The interstitial part is the thinnest, lying within the muscle layer of the uterus and measuring 1–2 cm. This tract can be visualized by transvaginal ultrasound in a transversal scan of the uterus at the level of the fundus, following the
endometrial echoes in a lateral direction (Fig. 3.44). It appears as a thin hyper-echogenic streak that begins in the endometrium and runs towards the external profile of the uterus.

Fig. 3.44. Interstitial part of the Fallopian tube visualized on a transversal section at the level of the fundus as a thin echogenic line (arrows) through the right and left aspect of the uterine wall

The isthmic part is thin and tubular and runs adjacent to the lateral margin of the uterus for several centimetres. The infundibular section is longer and larger. The distal (ampullar) extremity opens freely into the abdominal cavity, ending with the fimbriae, thin fringe-like structures that surround the abdominal orifice of the tube.

The salpinges are difficult to visualize with ultrasound, except when there is a moderate amount of free fluid in the abdomen, which surrounds the tube and acts as an ultrasound contrast agent (Fig. 3.45, Fig. 3.46).

Fig. 3.45. Free fluid in the pouch of Douglas and visualization of the tubal infundibular and ampullar tract
Paraovarian and paratubal cysts
Paraovarian and paratubal cysts account for about 10% of all adnexal cysts. They are distinguished as mesonephric (Wolffian ducts), paramesonephric or tubal (Müllerian ducts) and mesothelial on the basis of their origin. These cysts have common ultrasound characteristics, independently of their histological origin. They are usually anechoic cysts, with thin walls and well-defined margins. They rarely contain septa or papillae, with a few vessels. Useful diagnostic criteria for paraovarian cysts are visualization of a close but distinct ipsilateral ovary, the absence of a pericystic ovarian parenchyma and movement of the cyst from the contiguous ovary when light pressure is exercised with the vaginal probe (Fig. 3.47, Fig. 3.48).
Adhesions

Adhesions are suspected if palpation with the probe or abdominal palpation with the hand indicates that the ovaries or the uterus are adhering to adjacent structures (broad ligament, pouch of Douglas, bladder, rectum or parietal peritoneum). Sometimes, in the presence of pelvic fluid, fine septa (adhesions) can be seen between the ovary and the uterus or the peritoneum of the pouch of Douglas.

The sonographic sign of adhesions are:

- the presence of thin septa in pelvic fluid between organs (Fig. 3.49), with no or little vascularization in the septa and movement of these thin septa (filmy adhesions) by manual or probe palpation, looks like a sail;

Fig. 3.48. Paratubal cyst: free fluid in the pelvis and visualization of the tubal infundibular and ampullar tract and a small cyst close to the tube.

Fig. 3.49. Pelvic fluid and fine, thin septa (adhesions) can be seen between the uterus (a) and the peritoneum of the pouch of Douglas (b).
the presence of a pelvic peritoneal inclusion cyst, with fluid accumulation in the cul-de-sac or pelvis, walls identical to the pelvic wall and thin septa; fixed organs, whereby the uterus and ovaries, which are normally mobile and not adherent to the surrounding tissues by palpation with a probe or by abdominal palpation with the hand, appear to be fixed to each other.

**Tubal diseases**

*Inflammatory disease*

Inflammatory processes of the Fallopian tubes, or pelvic inflammatory disease, are a frequent and serious yet treatable disease that can lead to abscess formation or pelvic fluid accumulation. Over the years, it has become clear that the transvaginal ultrasound appearance of tubal inflammatory disease is typical and reproducible. Various ultrasound markers of tubal disease have been identified and placed in the context of the pathogenesis. Correct identification of the chronic sequelae resulting from previous inflammatory disease enables the observer to differentiate these ultrasound markers from unrelated diseases of the bowel, cystic ovarian neoplasia with papillary formation and other malignancies of the ovaries.

**Sonographic markers of tubal inflammatory disease**

Tubal inflammatory disease was identified with transvaginal ultrasound on the basis of shape, wall structure, wall thickness, extent of ovarian involvement and the presence of fluid (Timor-Tritsch, 1998).

**Shape**: on a longitudinal section, a pear-shaped, ovoid or retort-shaped structure containing sonolucent fluid or, sometimes, low-level echoes (Fig. 3.50).

**Wall structure**:

- incomplete septa (Fig. 3.50, Fig. 3.51), defined as hyperechoic septa that originate as a triangular protrusion from one of the walls but do not reach the opposite wall;
- cogwheel sign, defined as a sonolucent cogwheel-shaped structure visible in the cross-section of the tube, with thick walls (Fig. 3.52); or
- beads-on-a-string sign, defined as hyperechoic mural nodules measuring 2–3 mm and seen on the cross-section of the fluid-filled distended structure (Fig. 3.53).

**Wall thickness**: considered thick if ≥ 5 mm (Fig. 3.51 and 3.52) or thin if < 5 mm (Fig. 3.53).
Fig. 3.50. Longitudinal section of a hydrosalpinx, seen as a fluid-filled convoluted structure containing low-level echoes

Fig. 3.51. Acute salpingitis with incomplete septa and thick wall (> 5 mm)

Fig. 3.52. Transverse section of acute salpingitis: a sonolucent cogwheel-shaped structure is visible in the cross-section of the tube, with thick walls
Extent of ovarian involvement:

- none if the ovary appears normal and can be distinctly identified (Fig. 3.54);
- tubo-ovarian complex (Fig. 3.50) in which the ovaries and tubes are identified and recognized (Fig. 3.52), but the ovaries cannot be separated by pushing the tube with the vaginal probe; the woman also has the clinical signs and symptoms of acute pelvic inflammatory disease (Fig. 3.55, Fig. 3.56);
- tubo-ovarian abscess, in which an acutely ill patient with marked tenderness at the touch of the ultrasound probe shows total breakdown of the normal architecture of one or both the adnexa, with formation of a conglomerate in which neither the ovary nor the tubes can be separately recognized as such (Fig. 3.57). The classical pelvic abscess formation with total breakdown of separately identifiable tissues and speckled fluid is also regarded as a tubo-ovarian abscess.

**Presence of fluid:** free or in a pelvic peritoneal inclusion cyst. The latter is a sonolucent, fluid-filled accumulation in the cul-de-sac, the walls of which are identical to the pelvic wall, with thin adhesions between the organs in the pelvis (Fig. 3.49); the process is not acute, i.e. there is no tenderness upon touch with the vaginal probe or clinical signs and symptoms of an acute illness.
Fig. 3.54. Acute salpingitis: ovary is clearly seen and separate from the tube with thick walls.

Fig. 3.55. Acute salpingitis: the ovary (OV) is clearly seen but adherent to the tube (TU), with thick walls, incomplete septa and fluid dense content.

Fig. 3.56. Tubo-ovarian complex: the ovary is clearly seen and is adherent to the tube, with purulent exudate filling the lumen.
Correlation between ultrasound image and acute or chronic pelvic inflammatory disease

In a number of studies, the ultrasound images are classified as acute or chronic and, in each of these categories, one section depicts wall thickness, incomplete septa and wall structure. Once ovarian involvement is suspected or detected, the acute and chronic involvement of the pelvic organs is classified as tubo-ovarian complex or tubo-ovarian abscess. Late sequelae of possible inflammatory disease, such as pelvic peritoneal inclusion cyst or fluid, are frequent in women with a history of pelvic inflammatory disease.

**Wall thickness:** Women with acute disease have thick Fallopian tube walls (Fig. 3.51, Fig. 3.52, Fig. 3.54, Fig. 3.55), whereas overwhelmingly more women with chronic disease have a thin wall (Fig. 3.53, Fig. 3.58, Fig. 3.59).

**Wall structure:** Women with acute disease have the cogwheel sign, whereas the beads-on-a-string sign is present in women with chronic disease (Fig. 3.53, Fig. 3.59). Incomplete septa are present in both chronic and acute cases (Fig. 3.50, Fig. 3.51, Fig. 3.55, Fig. 3.58, Fig. 3.59).

**Tubo-ovarian complex** is common in women with acute disease and rare in women with chronic disease. **Cul-de-sac fluid** is more commonly seen in acute cases. **Palpable findings** are common in both acute and chronic cases. The bimanual palpatory pelvic examination before the scan or palpation with the probe often cause tenderness and pain in acute cases but sometimes also in chronic cases.

**Differentiation between tubo-ovarian complex and tubo-ovarian abscess**

These two entities are not only sonographically distinct, but also clinically different and require different therapeutic approaches. The tubo-ovarian complex is a first step in a process that may lead to abscess formation. A tubo-ovarian complex should be diagnosed if transvaginal ultrasound shows clear inflammatory features in tubal...
and ovarian structures (e.g. thick wall, cogwheel sign) (Fig. 3.51, Fig. 3.52, Fig. 3.55, Fig. 3.56). The term ‘tubo-ovarian abscess’ should be reserved for a later phase in this process, when total breakdown of the adnexal structures on one or both sides is seen (Fig. 3.57). At times, the presence of loculated, speckled fluid above the rectum (in the cul-de-sac) can be detected sonographically. This is consistent with pus and is probably due to debris from white blood cells, fibrin and degrading tissue.

Natural course of tubal inflammatory disease and ultrasound findings

The ultrasound classification of tubal inflammatory disease is based on its natural course. During the acute phase, if the tubal mucosa is involved in the inflammatory process, the tubal wall becomes thick and oedematous, and purulent exudate fills the lumen (Fig. 3.50, Fig. 3.51). Some exudate may also spill into the cul-de-sac through the fimbrial end of the tube. The ultrasound image reflects these pathological changes as the cogwheel sign, with a tubal wall that is ≥ 5 mm thick and highly vascularized (Fig. 3.52, Fig. 3.55, Fig. 3.56, Fig. 3.57). These are pathognomonic signs of acute tubal inflammation.

If the tubes become occluded at the fimbrial or the cornual end, mucus or pus will fill and distend the tubes, leading to entities called hydrosalpinx and pyosalpinx, respectively (Fig. 3.50, Fig. 3.51). The tubes become convoluted and both in situ and on ultrasound resemble the glass retorts used in laboratories, due to the presence of an incomplete septum; they are therefore known as retort-shaped tubes (Fig. 3.58, Fig. 3.60).

The progressive filling and ballooning of the occluded tube leads to a doubling-up or kinking of the hydro- or pyosalpinx (Fig. 3.60). The ultrasound equivalent of this process is the incomplete septum seen in both acute and chronic tubal disease (Fig. 3.58).

If the tube does not become occluded, some of the infectious pathogens spill into the pelvis and take advantage of ovulation, at which time a small defect on the ovary itself is obvious at the site of the ovulation. Bacteria invade during this incipient stage, usually only the ovary and the tube on one side. At first, the anatomy is
not broken down, and, if a laparoscopy or a laparotomy is performed at this stage, an inflammatory conglomerate is seen, with the ovary and the tube still recognizable as separate entities by transvaginal ultrasound (Fig. 3.54, Fig. 3.55, Fig. 3.56).

Fig. 3.59. Chronic hydrosalpinx: dilated tube with thin wall and beads-on-a-string sign

Fig. 3.60. (a)–(d) Three-dimensional evaluation and inverse mode of a retort-shaped hydrosalpinx
If treatment fails or is not applied, the acute inflammatory process progresses to its most severe phase, resulting in a full-blown tubo-ovarian abscess (Fig. 3.57). Only at a relatively later stage (days) does the process spread to the other side to involve the contralateral ovary and Fallopian tube. Therefore, an out-of-phase appearance of the two adnexa may be seen: one in which the process has advanced to the tubo-ovarian abscess stage and the contralateral one which lags behind, exhibiting all the signs of a tubo-ovarian complex in which the anatomy has not yet broken down.

The process may enter a chronic phase, characterized by a completely blocked tube in which fluid accumulates, distending the wall and rendering it very thin. The endosalpingeal folds almost disappear or become flattened and extremely fibrous. On cross-section of the tube, the pathological specimen and histological sections show these remnants of the fibrosed endosalpingeal folds (Fig. 3.53). Ultrasound examination also shows the typical dilated, thin-walled structure, studded with the echogenic remnants of the endosalpingeal structures, known as beads-on-a-string (Fig. 3.55, Fig. 3.58, Fig. 3.59). This ultrasound sign is a reliable marker of chronic tubal disease, e.g. hydrosalpinx. Hydrosalpinx can be the result of previous acute salpingitis and has also been described in women with a history of pelvic inflammatory disease or salpingitis or even hysterectomy. Hydrosalpinx can also develop in tubes occluded previously by ligation or cauterization. The ultrasound finding of a thin-walled, fluid-filled tube with the characteristics described here in women who have undergone hysterectomy or tubal sterilization is harder to explain; however, there is evidence that, in these cases, the fimbrial end of the tube may already have been occluded or give the typical ultrasound picture of a hydrosalpinx.

In the acute phase, a small amount of fluid may accumulate in the cul-de-sac or in other parts of the pelvis and persist for a variable length of time. Adhesions between various organs in the pelvis, formed during the acute phase of the inflammatory disease, may persist for months or even years (Fig. 3.49).

Tubal inflammatory disease and differential diagnosis from ovarian lesions

It is critical to differentiate tubal inflammatory disease from an ovarian tumour, whether benign or malignant. In the case of an acute inflammatory process, this is relatively easy, determined by the acute inflammatory features of the pelvic disease. Differentiation is more difficult when a diagnosis of chronic tubal disease with the beads-on-a-string sign and some septations must be differentiated from that of an ovarian cystic structure with small internal papillations and septa. In the case of a chronic hydrosalpinx, the mural lesions (beads-on-a-string) are small, almost equal in size and distributed around the thin wall, whereas papillary formations of an ovarian tumour are usually dissimilar in size and located along the wall, which may show variable thickness. If incomplete septa are present, these almost always indicate a Fallopian tube as the true septa of ovarian tumours are very seldom, if ever, incomplete.

For an accurate differential diagnosis of other adnexal lesions, each case must be placed in its appropriate clinical context. By combining the information provided by
the woman with the transvaginal ultrasound work-up of the pelvis, valuable ultrasound markers of inflammatory disease of the tubes and the ovary can be recognized and the appropriate diagnosis established.

**Tubal carcinoma**

Tubal carcinomas are the rarest tumours of the female reproductive system, with an incidence of 0.5% of all gynaecological tumours. Only about 1500 cases have been reported in the literature. The clinical characteristics and the response to cytostatic therapy are similar to those of ovarian cancer, but their ultrasound appearance may be different. Preoperative diagnosis of tubal cancer is difficult and is based on visualization of both ovaries, of normal dimensions and morphology, and an adnexal mass with malignant ultrasound characteristics, separated and distinct from the ovaries. These neoplasms often have an elongated oval shape (sausage-like); the cystic component is generally hypoechoic, and its appearance is similar to that of an adnexal inflammation at an advanced stage or a tubo-ovarian abscess.

Tumour markers (e.g. CA-125) may be only moderately increased. The persistence of the mass, its growth over a brief period and a lack of response to antibiotics should guide a differential diagnosis. Ultrasound features of peritoneal carcinomatosis are found in 30–40% of patients with tubal cancer at diagnosis. Otherwise, it appears as a uni- or bilateral adnexal mass, with a complex echo-texture and extensive, richly vascularized solid areas that can be visualized with transvaginal ultrasound.

**Tubal patency**

Tubal occlusion is the single most common cause of female infertility. Some degree of tubal disease, resulting in occlusion of one or both tubes, is found in one of three infertile women (30–50%), and the proportion is considered to be increasing. Evaluation of tubal status is generally the first step in an investigation of infertility factors in women. The usual methods for assessing tubal patency are hysterosalpingography and laparoscopic dye chromopertubation (lap-and-dye). The lap-and-dye test is the gold standard for tubal investigations; however, it involves anaesthesia and surgery, is expensive and often involves delays, as it is an inpatient procedure. Hysterosalpingography can be performed on outpatients but involves gonadal exposure to X-ray irradiation, may produce a hypersensitivity reaction to iodinated contrast medium and is 80–90% as accurate as lap-and-dye.

**Hysterosalpingo-contrast sonography**

Transvaginal hysterosalpingo-contrast sonography (HyCoSy) can be used to evaluate tubal patency. It involves the introduction of saline solution into the uterine cavity and the Fallopian tubes during transvaginal ultrasound; when free fluid is found in the pouch of Douglas, the patency of at least one tube can be deduced. Saline solution has the advantage of being completely safe and inexpensive. Although it is a useful negative contrast medium for visualizing intrauterine disease (sonohysterography),
saline is not an accurate medium for evaluating the state and patency of the Fallopian tubes. Combination of transvaginal ultrasonography with colour Doppler or ultrasound positive contrast media has increased the accuracy of this method.

To examine the Fallopian tubes, a positive contrast medium, such as air or albumin or galactose with micro-air bubbles, is used. These agents outline the lumina of the Fallopian tubes, giving a hyperechoic appearance. Use of contrast media (such as Echovist, Levovist and Infoson) facilitates evaluation of tubal patency by hysterosalpingo-contrast sonography; however, these contrast media are expensive, not available in many countries and not always accepted by women. The most readily available, least expensive contrast medium is saline solution mixed with air; when this solution is shaken, it produces a suspension of air bubbles which are easily seen when injected into the uterine cavity and the Fallopian tubes.

Hysterosalpingo-contrast sonography is performed as an outpatient procedure after a preliminary scan to detect the position of the ovaries and the interstitial part of the tubes. After insertion of a speculum, a 5-French salpingographic balloon catheter is placed in the uterine cavity and filled with 1–2 ml of air. This step ensures that the cervical canal is closed, prevents leakage of saline solution and air and keeps the catheter in position. A 20-ml syringe containing 15 ml of saline solution and 5 ml of air is prepared and shaken immediately before injection.

A vaginal ultrasound probe is then inserted, and a transversal section of the uterus is taken to localize the interstitial part of the tube. Saline solution is injected slowly and continuously through the catheter, and any resistance during injection is noted. Power Doppler can be used to locate the tubal area. Although colour Doppler imaging is not essential for evaluation of tubal patency, it might facilitate visualization of the passage of saline solution and localization of the tube. When the saline solution and air are injected, a flow of air bubbles through the tubes can be seen. The tube is followed as distally as possible by moving the probe slowly.

The salpinges should be sought and scanned methodically and continuously during injection, starting at the uterine cornu in a plane that also shows the interstitial part of the tube, and then scanning laterally to identify for the flow of air bubbles throughout the tube and near the ovaries. Each salpinx must be examined separately.

If the procedure becomes painful, the examination can be interrupted for a short time to allow any tubal spasm to pass. Hard pressure felt during injection of air and fluid is regarded as a sign of tubal spasm or occlusion. If the pressure does not decrease and no air bubbles are seen to flow from the tube, it is considered to be obstructed.

The criteria for tubal patency on hysterosalpingo-contrast sonography with saline and air contrast media are:

- the passage of air and saline through the interstitial part of the tube;
- detection of air bubbles moving around the ovary, even without visualization of the passage through the tube;
- detection of the solution and air bubbles in the pouch of Douglas;
- power Doppler evidence of the passage of saline solution.
Transvaginal hysterosalpingo-contrast sonography with saline and air solution is a relatively simple, safe, inexpensive, rapid, well-tolerated outpatient technique for determining tubal patency. Furthermore, transvaginal ultrasound accurately demonstrates various pelvic conditions that may be responsible for infertility, so that, in the same setting and at the same time, more information on the pelvis and tubal patency can be obtained. The accuracy and advantages of hysterosalpingo-contrast sonography over hysterosalpingography and lap-and-dye have been demonstrated, especially when the tubes are patent; poorer accuracy has been found in cases of tubal occlusion, especially when it is unilateral.

Several studies have suggested that hysterosalpingo-contrast sonography could be used in initial screening of infertile women; however, a reported false occlusion rate of 5–15% raises some concern. In contrast to hysterosalpingography, hysterosalpingo-contrast sonography does not allow imaging of the entire tube and its course. Use of ultrasound contrast media has been proposed to improve evaluation of tubal occlusion and for visualization of the tubal course. Ultrasound contrast media create an image because of the vibration of the bubbles caused by the ultrasound beam at low acoustic pressure. Even with contrast media, however, the false-positive rate for tubal occlusion is still 5–10%, because it is not always possible to visualize the entire tube due to either tubal spasm, only partial occlusion or overlapping by the ultrasound images of other organs (uterus, ovaries, intestine).

The contrast media generally used produce a contrast response, with an overlap between the tissue and the contrast response. To ensure that a signal is received only from the contrast medium, application of dedicated software to the vaginal probe and new contrast media have been proposed. This technique optimizes the use of ultrasound contrast media by means of low acoustic pressure and allows detection of the contrast medium by selecting the harmonic response of the microbubbles of the medium from the signals coming from insonated organs. The image displayed with this technique is due only to harmonic signals produced by contrast media microbubbles; broadband ultrasonic signals from surrounding tissue are filtered out completely, therefore obviating any overlap between the tissue and the contrast response.

When intrauterine injection of contrast medium is visualized by ultrasound with low acoustic pressure, the contrast medium is first seen in the tube, if it is patent proximally, and then spills into the abdominal cavity if the tube is distally and totally patent. Tubal occlusion can be assumed when the contrast medium remains concentrated within the uterus or the tubes and does not spill into the abdominal cavity, which remains hypoechoic (Fig. 3.61).

As the contrast medium is extremely hyperechogenic and can be visualized for several minutes, it is possible to study the tubal course and shape (Fig. 3.62).

Hysterosalpingo-contrast sonography associated with transvaginal scanning can be used for primary investigation of infertility in women on an outpatient basis. Hysterosalpingo-contrast sonography performed with a combination of air and saline is a quick, inexpensive, well-tolerated method for determining tubal patency, but it requires some experience. One of the most important advantages
of this technique is that information on tubal status and the uterine cavity can be obtained at the same time as the transvaginal ultrasound scan. Hysterosalpingo-contrast sonography performed with dedicated ultrasound contrast media and low acoustic pressure is an accurate method for obtaining information on tubal status and, in particular, on tubal occlusion. When combined with a transvaginal scan, it can replace a hysterosalpingogram and does not require a high degree of experience. If tubal occlusion is diagnosed by hysterosalpingo-contrast sonography, laparoscopy should be considered as the second-line procedure.

Fig. 3.61. Hysterosalpingo-contrast sonography with low acoustic pressure and new ultrasound contrast media. (a) Patent tube; the hyperechoic contrast agent is seen on the left in the uterine cavity, in the tube (note visualization of the tubal course), and on the right around the ovary. (b) Tubal occlusion; the hyperechoic contrast medium is seen only in the uterine cavity and not laterally to the uterus nor in the pelvis, which is anechoic.

Fig. 3.62. Patent tubes on hysterosalpingo-contrast sonography with low acoustic pressure and new ultrasound contrast media. The hyperechoic contrast clearly shows the course of the tubes; the organs beneath the tubes are excluded from the image due to the harmonic signal response of the contrast medium microbubbles and to the broadband ultrasonic signals from surrounding tissue filtered out by the software. (a) Tube with an angle. (b) Tortuous tube.
Normal anatomy, basic examination and biopsy technique

Indications  
Preparation  
Examination technique  
Normal findings  
Biopsy  
New ultrasound techniques

Benign lesions

Cysts  
Acute mastitis and abscesses  
Haematoma  
Fibroadenoma  
Phyllodes tumour  
Intraductal papilloma  
Intraparenchymal lymph nodes  
Fibrocystic alterations  
Fibrolipoadenoma  
Galactocele  
Adenoma  
Liponecrosis  
Male breast disease

Malignant lesions

Breast cancer  
Role of ultrasound  
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Breast

Normal anatomy, basic examination and biopsy technique

Indications
Breast ultrasound is a non-invasive imaging technique for diagnosing breast disease. Mammography is a well-established imaging tool for screening breast cancer in order to reduce its inherent mortality by an early diagnosis. Even so, mammograms do not detect all breast cancers: some breast lesions and abnormalities are not visible or are difficult to interpret on mammograms. In dense breasts (a lot of breast tissue and less fat), many cancers can be hard to see on mammography.

Breast ultrasound can be used in several ways. The commonest application is for investigating an area of the breast in which a problem is suspected. A palpable lump or a lump or density discovered by X-ray imaging (mammogram) can be evaluated further by ultrasound. This is especially helpful for distinguishing between a fluid-filled cyst and a solid mass.

Breast ultrasound is often the first examination performed to evaluate masses in women under 35 years of age, whose mammograms can be difficult to interpret because of the density of their breast tissue. Ultrasound may also be used in women for whom radiation is contraindicated, such as pregnant women, young women and women with silicone breast implants.

Breast ultrasound is also used to observe and guide a needle in several interventional procedures, including cyst aspiration, fine-needle aspiration, large-core needle biopsy and needle localization in surgical breast biopsy. Biopsies guided by ultrasound have distinct advantages: they are generally less costly than surgical biopsies, and, if the abnormality to be sampled can be seen on both a mammogram and ultrasound, an ultrasound-guided biopsy is often more comfortable for the woman, as no compression is necessary.

Preparation
The ultrasound unit should be on the woman’s right. The radiologist takes images with the right hand and operates the machine with the left hand. The woman is in a supine position with a raised arm, and the examiner sits at her level. A raised arm
flattens and immobilizes the breast on the chest wall by tension on the pectoral muscles. This position is the same as that used for breast operation and ensures the reproducibility of the examination. Larger breasts shift laterally, creating non-uniform tissue distortion. In this case, the radiologist should ask the woman to roll to allow study of the lateral quadrants. Asking the women to assume a sitting position might help the examiner to localize the lesion if a palpable mass cannot be found when she is in the supine position.

Before the procedure, clear gel is applied to the woman’s skin to allow smooth movement of the transducer over the skin and to eliminate air between the skin and the transducer. The transducer is held at the base, in maximum contact with the fingers and palm. The examiner’s forearm rests lightly on the woman’s torso, and the movement of the transducer is controlled by the wrist, not the entire arm.

**Examination technique**

Real-time hand-held scanners should include a linear array and a high-frequency transducer operating at a frequency of 7.5–10 MHz or more, which provides good tissue penetration to 4–5 cm. The depth of focus is placed at ≤ 3 cm. The time-compensated gain curve should be adjusted so that fat is uniformly grey, from the subcutaneous tissue to the chest wall. Improper adjustment of technical parameters can lead to suboptimal images and produce artefactual echoes that can result in misdiagnosis. Routine calibration of the unit and evaluation of the unit’s performance with a breast phantom help prevent technical errors.

To ensure that the field of view includes all the breast tissue, from the skin surface to the chest wall, the operator should see the pectoral muscles and the chest wall at the bottom of the screen. In order to reduce reflective and refractive attenuation, the transducer should be kept parallel to the breast surface and the ultrasound beam perpendicular to the breast tissue by applying gentle, uniform pressure. Use of a Doppler probe during an ultrasound procedure allows assessment of blood flow within the breast.

The breast is moveable and contains few anatomical landmarks. In order to achieve complete coverage, a systemic scanning pattern is needed, involving sagittal, transverse, radial and tangential scans. Radial scanning is critical for detecting intraductal mammary lesions. If it is not viewed along the long axis of the duct, a mass will be difficult to detect; it is relatively easy to see a mass in the duct when the transducer is aligned along it.

An ultrasound examination should always be complemented by a study of the axillary regions.

Palpation during scanning allows precise localization of palpable abnormalities. It enables the examiner not only to find subtle lesions, but also to determine
whether normal structures, such as fat lobules and thickened Cooper ligaments, are responsible for a palpable abnormality.

Once an area of interest or a mass is identified, the image should be large enough to fill the monitor or screen, so that its important features can be evaluated. The focal zone, the time-compensated gain curve and the depth-compensated gain curve should be reset on the lesion. Each image should be labelled as pertaining to the right or left breast, the quadrant or clock position, the scanning plane (radial, longitudinal or transverse) and the number of centimetres from the nipple.

A good ultrasound study is difficult to obtain if the woman cannot remain quietly in one position. Obesity and excessively large breasts may interfere with breast ultrasound.

The examination may take from 20 to 40 min.

**Normal findings**

Each breast has 15–20 sections, called lobes, which are arranged in a radial fashion from the nipple. Each lobe is triangular and has one central excretory duct that opens into the nipple. Each lobe has many smaller lobules, and the spaces between the lobules and ducts are filled with fat. Fibrous strands of connective tissue (Cooper ligaments) extend from the skin to the underlying pectoralis fascia and are arranged in a honeycomb-like structure surrounding the breast ducts and fat (Fig. 4.1). The most superficial lobes are attached by their summit to the superficial layer of the fascia and constitute the Duret crests. The deepest crests connect the anterior lobes to the deep layer through the suspensory Cooper ligament. The ratio of supporting stroma to glandular tissue varies widely in the normal population and depends on the woman’s age, parity and hormonal status. In young women, breast tissue is composed mostly of dense glandular tissue; with age, the dense tissue turns into fat. Each breast also contains blood vessels and vessels that carry lymph.

![Anatomical drawing of the breast](image-url)
Skin

The skin line is a bright linear echo immediately under the transducer (at the top of the image). The skin line is normally 2–3 mm thick and has an echo-poor layer of subcutaneous fat immediately beneath it (Fig. 4.2, Fig. 4.3).

Subcutaneous fat

Fat in the breast appears dark or echo-poor. The only exception to echo-poor fat in the breast is echogenic fat in the lymph node hilum. Subcutaneous fat lies between the skin and the breast parenchyma; it is homogeneous and variable in quantity (Fig. 4.2, Fig. 4.3).
Cooper ligaments
Cooper ligaments are thin, linear, echogenic structures that support the surrounding fat and glandular elements. Attenuation of ultrasound by Cooper ligaments (especially in the subcutaneous fat region) may be mistaken for a lesion. The examiner should change the angle of the transducer or compress it over the area to exclude a lesion (Fig. 4.1, Fig. 4.3).

Parenchyma
Breast parenchyma appears echogenic, with intermediate echogenicity between the echo-rich connective tissue and the lower echogenicity of fat tissue, and lies beneath the subcutaneous fat. The pattern of parenchymal echogenicity (mixed) depends on age, glandular density, menstrual cycle phase, pregnancy and lactation (Fig. 4.4, Fig. 4.5).

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Fig. 4.4. Dense breast: high echogenicity of parenchyma

Fig. 4.5. Fatty breast: low echogenicity of parenchyma
Retromammary fat
The retromammary fat is posterior to parenchyma (Fig. 4.1).

Pectoral muscle
The pectoral muscle (anterior to the ribs) is an echo-poor structure of varying thickness that contains thin lines of supporting stroma coursing along the long axis of the muscle (Fig. 4.1, Fig. 4.2).

Ribs
The ribs, contained in the intercostal muscles, are round or oval in cross-section and cause an intense acoustic shadow due to bone attenuation. High-resolution transducers may display calcifications in the anterior portions of cartilaginous elements of the ribs (Fig. 4.1, Fig. 4.2, Fig. 4.6).

Fig. 4.6. Ribs are visualized in cross-section as round or oval structures; calcifications can be seen in the anterior portion

Pleura
The pleura gives echogenic lines deep to the ribs that move with respiration (Fig. 4.1, Fig. 4.2).

Nipple
The nipple is an echo-poor structure consisting of dense connective tissue and subareolar ducts, which can cause posterior acoustic shadowing. Sound attenuation by the nipple improves with pressure (Fig. 4.1, Fig. 4.7).

Ducts
Ducts are tubular branching structures leading to the nipple (Fig. 4.1, Fig. 4.7).
Lymph nodes
Lymph nodes appear as solid, oval structures with a thin, homogeneous, echo-poor cortex and an ovoid, echogenic, fatty hilum. Lymph nodes are generally visualized in the axilla region (Fig. 4.8). Small lymph nodes with normal findings can also be detected within the breast (Fig. 4.9).

The accuracy of ultrasound depends on the operator, and considerable observer variation in the descriptions and assessments of breast lesions have been reported. Referring physicians, other radiologists and women would benefit from standardization of the terms for characterizing and reporting lesions. Therefore, a lexicon of descriptors and assessment categories has been drawn up by the American College of
Radiology to promote the clinical efficacy of breast ultrasound. The lexicon (Breast Imaging Reporting and Data System) includes ultrasound descriptors for shape, orientation, margins, lesion boundary, echo pattern, posterior acoustic features and alterations to surrounding tissue. On the basis of these descriptors, each lesion was assigned an assessment category associated with the most appropriate clinical management of the woman (Table 4.1).

To perform a correct breast ultrasound examination, the following diagnostic algorithm can be used:

1. scanning of the entire breast
2. detection of lesion
3. adjustment of technical parameters
4. study of lesion
5. classification of lesion
6. referral.

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**Table 4.1. Breast Imaging Reporting and Data System, final assessment categories**

<table>
<thead>
<tr>
<th>Category</th>
<th>Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Need additional imaging</td>
</tr>
<tr>
<td>1</td>
<td>Negative</td>
</tr>
<tr>
<td>2</td>
<td>Benign finding(s)</td>
</tr>
<tr>
<td>3</td>
<td>Probably benign finding; short-interval follow-up suggested</td>
</tr>
<tr>
<td>4</td>
<td>Suspected abnormality; biopsy should be considered</td>
</tr>
<tr>
<td>5</td>
<td>Highly suggestive of malignancy; appropriate action should be taken</td>
</tr>
<tr>
<td>6</td>
<td>Biopsy-proven malignancy; appropriate action should be taken</td>
</tr>
</tbody>
</table>
Biopsy
Pre-biopsy work-up
Non-palpable, sonographically detected breast lesions are amenable to preoperative localization or percutaneous biopsy. Informed consent is an important part of these procedures: the woman should be informed about the risks, benefits and alternatives to biopsy. Possible risks include inability to sample the lesion, haematoma, bleeding, pneumothorax and breast infection. Local anaesthesia is routinely used for breast biopsy and preoperative needle localization. A common local anaesthetic for percutaneous breast procedures is lidocaine or Carbocaine, which is injected through a 25-gauge needle. Sterile technique is always recommended.

Biopsy technique
Preoperative needle localization
With the woman in the supine position, the radiologist rolls her until the needle path is directed safely away from the chest wall. Under direct ultrasound visualization, the radiologist plans the path of the needle to the lesion. Once the needle is within the lesion, the hook-wire is placed and the needle is removed.

Fine-needle aspiration or core-needle biopsy
For fine-needle aspiration, the radiologist introduces a needle (generally 21–25 gauge) in the plane of the transducer under direct visualization to show the entire shaft of the needle and the lesion to prevent pneumothorax. Once the needle is within the lesion, the material for cytological evaluation is aspirated with a to-and-fro movement.

For core biopsy, the radiologist determines whether the lesion is in a safe location (away from the chest wall) and calculates the needle throw to ensure that the core trough is in the middle of the lesion. In a core biopsy (generally with an 18- to 14- or 11-gauge needle in the case of vacuum-assisted biopsy), the skin is sterilized, and the core needle track is anaesthetized under ultrasound with a fine needle that reproduces the core biopsy trajectory. A scalpel is used to make a skin nick to introduce the large-core biopsy needle. Under direct ultrasound, the large-core biopsy needle is introduced into the breast to the edge of the lesion, and the biopsy core needle is used. The core is harvested, and direct pressure is exerted on the breast.

New ultrasound techniques
New ultrasound techniques, such as tissue harmonic imaging, spatial compound, ultrasound elastography and three-dimensional ultrasound, have improved the quality of ultrasound breast images and show promise for diagnosing cancerous breast lesions in a non-invasive manner.

In harmonic imaging, the ultrasound machine scans images at twice the frequency transmitted. This can suppress reverberation and other near-field noise, but it may limit the depth of penetration. Harmonic imaging reduces the possible number
of complex cysts or solid masses seen on breast ultrasound and increases the examiner’s confidence that a lesion is in fact truly cystic and benign. The procedure may also better define the boundaries of lesions, which is important for distinguishing benign from malignant lesions.

In **spatial compound imaging**, information is obtained from several different angles of insonation and is then combined to produce a single image at real-time frame rates. Because images are averages from multiple angles, the image artefacts inherent to conventional ultrasound are reduced. Spatial compound imaging has also been shown to reduce speckle artefacts, improve visualization of low-contrast lesions, enhance tumour margins and improve images of the internal architecture of solid lesions and microcalcifications.

**Elastography** is a low-frequency vibration technique used to evaluate the elastic properties of tissues. It is performed by applying slight compression and comparing images obtained before and after compression.

**Three-dimensional ultrasound**: Two-dimensional transducer arrays can now produce three-dimensional ultrasound images, which have the advantage of being more rapid and reproducible and may solve the problem of screening ultrasound. Screening ultrasound has great potential, but screening the entire breast sonographically is labour-intensive and time-consuming for radiologists. A screening test should be simple, relatively cheap and, ideally, not require the presence of a physician. Screening by a technician or sonographer with three-dimensional ultrasound would permit a radiologist or another physician to review the data set in multiple scan planes, including radial planes.

**Benign lesions**

**Cysts**

Cysts are the commonest benign diseases of the breast found on ultrasound study. They are most often observed in pre-and perimenopausal women but sometimes occur in postmenopausal women, particularly in those receiving hormonal replacement therapy (estrogens). Under ideal conditions with suitable equipment, ultrasound can identify even 2- to 3-mm cysts and differentiate them from solid lesions with 95–100% accuracy. Differentiation between fluid-filled and solid lesions is the major function of sonography.

**Simple cysts** (Fig. 4.10) are defined by precise ultrasound characteristics. They are echo-free, roundish or oval, with well-defined anterior and posterior margins and posterior enhancement. A lesion with these features can be classified as a simple cyst and thus considered a benign lesion not requiring additional assessment, interventional procedures or follow-up. Ultrasound study of a simple cyst can, however, present a number of difficulties. In 25% of cases, posterior enhancement is not seen, especially in deeply located cysts, as the acoustic attenuation caused by adjacent
muscles and costal cartilage modifies the posterior enhancement usually associated with a fluid structure. The problem can often be overcome by scanning from different angles, by changing the woman’s position or by probe compression.

Sometimes there is posterior beam attenuation behind the central portion of the cyst, due to the presence of calcifications deposited along the cystic wall. This artefact is typical of long-standing formations. Calcifications within the cyst (milk of lime) appear as structured echoes, which are mobile with changing posture and often lack the characteristic posterior attenuation of the beam. Inner echoes can be due to reverberation artefacts, which tend to involve the anterior margin of the lesion while the posterior margin remains evident and well defined. Careful equipment setting, such as precise focusing and correct gain adjustment, will optimize the diagnostic information.

Most lesions with inner echoes, septations and posterior enhancement are complex cysts (Fig. 4.11), which are filled with protein or debris, mostly secondary to haemorrhagic or inflammatory phenomena. Ultrasound-guided aspiration of the lesion’s content confirms the diagnosis and leads to cyst resolution (Fig. 4.12, Fig. 4.13) with no need for surgical excision. Each detail of a cyst should be carefully evaluated: markedly thickened walls and papillary lesions vegetating within the lumen can indicate a suspected malignant lesion, such as an intracystic carcinoma or a carcinoma with central necrosis (Fig. 4.14, Fig. 4.15). In these cases, surgical excision may be indicated, as cytological examination of the inner fluid is not alwaysagnostically reliable.

Sebaceous cysts can also occur in the breast, although they are much commoner in the back and neck. These benign lesions, containing keratin and with a capsule of squamous epithelial cells, often appear to be solid, both clinically and at mammography. On ultrasound, they appear as well-marginated formations containing uniformly distributed low-level echoes with evident posterior enhancement.
Fig. 4.11. Complex cyst: lesion with inner echoes, well-defined margins and posterior enhancement

Fig. 4.12. Ultrasound-guided aspiration of echo-poor lesion (complex cyst)

Fig. 4.13. Disappearance of the lesion content leads to cyst resolution and confirms the diagnosis
Acute mastitis and abscesses

Acute mastitis, although most common in breastfeeding women, can also affect other women. In most cases, the diagnosis is clinical. In women who do not respond adequately to even prolonged antibiotic therapy, the presence of an abscess should be excluded, because in these cases the elective treatment is surgery.

On ultrasound, **uncomplicated mastitis** appears as an echo-rich area with blurred margins and an inhomogeneous echoic structure (Fig. 4.16, Fig. 4.17). **Abscesses** appear as fluid-filled focal lesions. Their overall morphology varies from echo-free to echo-poor. Inner echoes, sometimes with fluid–fluid or fluid–debris levels, inner septations and posterior enhancement, are frequent. An abscess cannot, however, be distinguished definitively on sonography from a non-infectious fluid collection. Ultrasound can be used to guide aspiration or definitive drainage.
A differential diagnosis of inflammatory carcinoma is not always possible, as some have features that are similar to or even indistinguishable from those of mastitis or abscess (Fig. 4.18), both clinically (diffuse cutaneous thickening, reddening, erythema and generalized oedema) and sonographically.
Haematoma

Breast haematoma may occur after an intervention or breast trauma. On ultrasound, it appears as an echo-rich to echo-free, well-marginated lesion, depending on its age and organization (Fig. 4.19).

Fig. 4.19. Breast haematoma, seen as an inhomogeneously echo-poor, well-marginated lesion

Fibroadenoma

Fibroadenomas are the most frequent solid lesions in women of premenopausal age. They are composed of epithelial cells and fibrocytes. Most are single lesions, but in 10–20% of cases they are multiple or bilateral. Fibroadenomas usually stop growing once they reach 2–3 cm (maximum diameter), unless there is abnormal hormonal stimulation, such as during pregnancy or in postmenopausal women under replacement therapy. Usually, they regress or undergo hyaline degeneration after menopause.
While not pathognomonic, the ultrasound features are a homogeneously echo-poor oval or roundish formation with regular or multilobular margins and no posterior beam attenuation or posterior enhancement (Fig. 4.20). These four features are present in only a small percentage (about 16%) of cases: 15–31% of lesions show multilobular margins and 25–58% show irregular margins. In over 11% of fibroadenomas, the pattern of inner echoes ranges from echo-rich to isoechoic, and inner echoes of inhomogeneous distribution are present in 12–52% of lesions, probably indicating the presence of hyaline necrosis, calcifications and fibrosis. In 9–11% of cases, there is posterior beam attenuation.

A definitive differential diagnosis of a fibroadenoma from a malignant lesion cannot be established on the basis of ultrasound criteria alone. In 10–25% of cases, breast tumours have circumscribed margins and benign ultrasound features. Use of the ratio between the axial diameter and the anteroposterior diameter of the lesion has been proposed as a fairly reliable criterion for differential diagnosis, with a suggested cut-off of 1.4. Higher ratios have been observed for most fibroadenomas but only rarely for tumours. Fibroadenomas can be difficult to identify in predominantly fibroadipose breasts, and use of high-frequency probes and the second harmonic may increase the detection rate.
Phyllodes tumour
Phyllodes tumour is a rare fibroepithelial tumour accounting for 0.3–1.5% of all breast tumours and 2.5% of all fibroepithelial tumours. Its relation to fibroadenoma is not clear. They show high cellularity, a sarcoma-like stroma and often contain fluid areas; they have a higher cell count, and the myxoid stroma is more evident than in normal fibroadenomas. These tumours are found mainly in women in the 5th to 6th decade of life and rarely in women < 20 years. Most phyllodes tumours are benign, but the differential diagnosis between benign, malignant and borderline lesions is based on histological appearance. Clinically, most phyllodes tumours are palpable large masses with alternating periods of rapid growth and remission. On ultrasound, they are solid, well-marginated, oval or lobulated formations. Smaller lesions are practically indistinguishable from fibroadenomas. In larger lesions, the presence of small cyst-like fluid collections, while not pathognomonic, suggests the diagnosis (Fig. 4.21).

Fig. 4.21. Phyllodes tumour, seen as a large mass with complex echo structure and small internal cyst-like fluid collections

Intraductal papilloma
Intraductal papillomas are benign lesions characterized by epithelial proliferation protruding into the ductal lumen around an axis of connective and vascular tissue of variable thickness. Solitary papillomas are usually retroareolar (Fig. 4.22, Fig. 4.23), affect the main lactiferous ducts and are often accompanied by disorders of the nipple (haemorrhagic or serohaemorrhagic secretion). Papillomas growing within the terminal ducts and lobules are usually peripheral and tend to be multiple.

On ultrasound, they are represented by solid formations (when sufficiently large to be visualized) protruding into a usually ectatic duct, which allows their visualization. Use of high frequencies helps detect smaller lesions.
Intraparenchymal lymph nodes

Lymph nodes within the breast parenchyma are usually located in the upper external quadrants and may be palpable. On ultrasound, normal lymph nodes appear as well-circumscribed formations of roundish, oval or lobulated morphology, echo-poor to the surrounding parenchyma, often with an echo-rich centre representing the adipose hilum (Fig. 4.24). Pathological processes involving the axillary nodes can extend to the intraparenchymal nodes, which usually appear enlarged and destructured, that is, homogeneously echo-poor, globular, with a diffusely or focally thickened cortex in the absence of an echo-rich hilum (Fig. 4.25).
Fibrocystic alterations

Fibrocystic alterations are found clinically in 50% of women but histologically in about 90%. Histological abnormalities involving both the fibrous tissue and the glandular parenchyma include exuberant proliferation and growth of connective tissue, ductal cystic dilatation and ductal or lobular cell hyperplasia.

**Fibrocystic mastopathy or benign mammary dysplasia** occurs mainly in young women (25–45 years) and is characterized clinically by diffuse nodularity, palpable mainly in the upper external quadrants and associated with more pronounced pain during the menstrual cycle. On ultrasound, localized mastopathy appears as poorly margined, echo-rich areas with inner cystic formations of variable dimensions, some with thickened and blurred walls indicating inflammatory phenomena, occurring mainly during periods of high hormonal stimulation (Fig. 4.26).
Sclerosing adenosis is a fibrocystic disorder characterized histologically by intralocular fibrosis and proliferation of small ducts or acini. On ultrasound, it can appear heterogeneous, depending on the predominant component involved in proliferation: as a large, solid formation with posterior beam attenuation when the fibrous component is widely involved, or as a macrocystic cluster with numerous acoustic interfaces and frequent calcium deposits along the walls when the fluid component is prevalent (Fig. 4.27).

Fig. 4.26. Localized fibrocystic mastopathy: seen as a poorly margined, echo-rich area with inner cystic formations of variable dimensions

Fig. 4.27. Sclerosing adenosis, seen as a large, solid, inhomogeneously echo-poor formation with indistinct margins and an echo-rich halo
**Fibrolipoadenoma**

Fibrolipoadenoma is a rare benign tumour, also called a hamartoma, usually found in maturity. It consists of the contemporary presence of epithelial structures (such as lobules and ducts) and a mesenchymal component (represented by fibrous and adipose tissue). Fat, fibrous and glandular tissue can be present in various proportions, which determine the ultrasound appearance of the lesion. A well-defined nodular formation, often with gentle lobulated contours, of mixed, inhomogeneous appearance is seen, with echo-rich areas representing the fibroglandular component, and echo-poor areas representing the adipose component (Fig. 4.28).

**Galactocoele**

Galactocoele is a benign cystic swelling that appears during breastfeeding or immediately after. It is due to obstruction of a lactiferous duct, with consequent stagnation of milk secretion and the appearance of a milk-containing pseudocyst. On ultrasound, it appears as a clearly margined, roundish or oval formation of mixed echo-free–echo-poor morphology, representing the presence of inner, mostly unstructured, mobile and coarse echoes, depending on the degree of milk coagulation (Fig. 4.29). Chronic galactocoele may show marked ultrasound absorption and, consequently, clear posterior attenuation, due to the formation of a dense, absorptive inner precipitate.
Adenoma
Tubular adenomas are benign tumours composed of numerous glandular formations clinging together, of uniform dimensions, lined with a single layer of epithelial cells. Adenoma of the nipple is a relatively rare benign lesion that affects mainly nulliparous women in their 40s to 50s. Clinically, on palpation, a retroareolar nodule is found, sometimes associated with nipple erosion, inversion and secretion. The nodule is a proliferation of glandular tubules involving the large retroareolar lactiferous ducts, which may show epithelial cell hyperplasia with a solid papillary architecture. Frequently, there is associated apocrine or squamous metaplasia and dense stromal fibrosis, with no evidence of a real capsule, sometimes with signs of

Fig. 4.29. Galactoceole, seen as a clearly marginated, oval formation with an echo-poor pattern indicating the presence of inner, mostly unstructured, mobile and coarse echoes representing coagulated milk

Fig. 4.30. Lactating adenoma, seen as a large, echo-poor area with blurred, poorly defined posterior margins, located behind the nipple and involving the main retroareolar ducts
distortion and pseudo-infiltration of the ductal component (Fig. 4.30). On ultrasound, tubular adenomas appear as echo-poor areas with blurred, poorly defined margins, located immediately behind the nipple, often poorly distinguishable or differentiable from a malignant lesion, especially if there is abundant fibrosis causing posterior beam attenuation.

**Liponecrosis**

Liponecrosis is an infrequent disease, occurring mainly in obese and middle-aged women. It may be a consequence of rupture of dilated ducts or cysts but is most frequently traumatic or iatrogenic in origin (after breast surgery). The lesion is unilateral, and, if palpable, it appears as a small indolent nodule with a regular surface, poorly mobile, at times associated with skin retraction or an area of ecchymosis. It is caused by adipocyte necrosis and by the inflammatory reaction consequent to the release of lipid material through the cell membranes, typical of foreign body reactions, followed by the reparative phase, with formation of a capsule around the fatty material (lipophagic granuloma). As the process becomes chronic, a fibroelastic reaction occurs, with the formation of a scar and possible retraction of the overlying skin. At times, calcium salts may deposit as microcalcifications within the liponecrotic area.

On ultrasound, the appearance can be extremely heterogeneous. Liponecrosis can appear as a simple cyst, with typical posterior enhancement, as a complex cyst, roundish and echo-free, with small inner echogenic nodules (Fig. 4.31), as a straight or S-shaped band, or as an inhomogeneously echo-poor area with blurred margins, roundish or oval, at times with moderate posterior beam attenuation. Medical history and comparison with mammograms play major roles in differential diagnosis.

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**Fig. 4.31.** Liponecrosis, seen as an inhomogeneously echo-poor area with blurred margins, irregularly roundish, with moderate posterior beam attenuation, located near a surgical scar
Male breast disease

The most frequent benign disease involving the male breast is so-called gynaecomastia, which is bilateral hyperplasia of the breast parenchyma. It should not be mistaken for pseudogynaecomastia, with an increased adipose component. This is readily observed on ultrasound, with the volumetric increase as well as with the typical diffuse echo-poor appearance of adipose breast. The incidence of gynaecomastia varies in relation to age, with a high prevalence in puberty and a peak (about 50% of cases) in adolescents up to 16 years. In most cases, it regresses spontaneously over some months. The prevalence increases again at older ages (> 50 years) due mainly to metabolic and pharmacological causes. The examination used preferentially is ultrasound, mainly to distinguish benign disease from male breast carcinoma.

Both on X-ray and ultrasound, three types of gynaecomastia are found: the nodular form, the dendritic form and the glandular form. The last is readily interpreted; it mimics the female breast in the florid phase, with the typical echo-rich appearance of parenchyma. The nodular form is usually retroareolar, echo-poor, with regular margins and contours, often accompanied by pain on palpation (Fig. 4.32).

The dendritic form is typically echo-poor and is found in the retroareolar area (Fig. 4.33). It is often associated with echo-poor infiltration of the posterior tissue and is not readily distinguishable from a malignant neoplasm. In these cases, ultrasound can be used for a guided biopsy.
Breast cancer is the most frequent malignant female cancer, occurring in 8–9% of women at some time in their lives. Epidemiological studies have shown a continuously increasing incidence of this disease, especially among women aged 45–65 years. Increases have also, however, been observed among older women, with the increase in natural human life, and, for unknown reasons, among younger women. The increase among women < 30 years is particularly worrying. Although the incidence of breast cancer is increasing linearly and continuously, mortality from this disease began to decrease from the second half of the 1980s as a result of early diagnosis and improved treatment.

Breast cancer is generally more frequent in urban than in rural populations and is 8–10 times more frequent in western and rich populations than in the poorest areas of the world. Several studies of lower-risk populations that have emigrated to countries with higher risk suggest that the reasons for the differences in incidences include the physical environment and cultural background. Notwithstanding knowledge about the risk factors for breast cancer, the reasons for the large international differences in the incidence of this disease are unknown, and, in countries with high incidences, it is not possible to identify subgroups of the population with a high concentration of cases on which to focus greater attention for early diagnosis.

The most useful criteria for identifying women at higher risk are age and family factors, such as a family history of breast cancer and a personal history of previous breast cancer. Despite the complex epidemiology of breast cancer, the list of further risk factors includes: null parity, higher age at first pregnancy, age at menarche, higher age at menopause, total calories consumed, postmenopausal obesity, alcohol

Fig. 4.33. Dendritic gynaecomastia, seen as an echo-poor, roundish lesion in the retroareolar area, with indistinct margins, associated with clear infiltration of the surrounding tissue
use, thorax irradiation, benign proliferative mastopathy, higher grade of education, use of hormonal replacement therapy, a higher level of low-density lipoprotein and a lower level of high-density lipoprotein and oxidative stress.

**Role of ultrasound**

Ultrasound examination of the breast is not an alternative to mammography but rather complementary, providing different information. It is particularly useful for examining young, dense breasts, for which mammography is less sensitive, and in pregnancy. Sometimes, ultrasound is the only means for understanding the nature of a mammographic abnormality or a palpable lesion, with adjunctive criteria, and can also be used as a guide during biopsy.

Ultrasound examination of the breast is conducted according to the criteria of the American College of Radiology. Accordingly, all signs of a suspected malignant lesion must be recorded: shape (irregular), orientation (not parallel to the skin), margins (not circumscribed), boundaries (echogenic halo), echo pattern (echo-poor), posterior acoustic features (shadowing), microcalcifications if present and vascularity (intra- and peri-lesional vascular spots on colour Doppler examination). The presence of these features, and particularly their association, supports a suspicion of a malignant lesion and thus the need for biopsy.

Breast lesions often represent benign conditions, such as cysts or fibroadenomas. If their diagnosis is verified, they are not a clinical problem for women.

**Sonographic features**

**Premalignant lesions and in situ carcinomas**

Epithelial malignant cancers account for 98% of all malignant breast neoplasms, including ductal carcinoma in situ, invasive ductal carcinoma and invasive lobular carcinoma. Differentiation of these forms is useful for defining the prognosis and therapy.

Ductal carcinoma in situ is constituted of a group of neoplastic cells inside the basal membrane, whereas the neoplasm becomes invasive if some neoplastic cells disrupt the membrane. The most frequent mammographic sign (60–80% of cases) of ductal carcinoma in situ is the presence of an isolated cluster of microcalcifications; in multifocal and multicentric forms, more than one cluster is located in the same or in different quadrants. Some microcalcifications, however, are associated with a nodular or spiculated mass (15–30%) or a nodular or spiculated opacity without microcalcification (10–15%). Generally, mammographic examination often underestimates the real extent of a ductal carcinoma in situ, particularly low-grade lesions. In these cases, ultrasound examination shows only the microcalcifications and does not identify their morphology clearly (as mammography does). Sometimes, a small, echo-poor lesion can be seen, with or without internal calcification. The distribution of the actual microcalcifications within a duct can sometimes be seen, especially when high-frequency ultrasound transducers are used.
Invasive carcinomas

**Invasive ductal carcinoma** is the most frequent malignant breast lesion; 3–5% of cases are multifocal and 10% of cases are multicentric. On ultrasound examination, an invasive ductal carcinoma is usually echo-poor, irregular, without circumscribed margins or shadowing. The size of the lesion measured by ultrasound correlates exactly with the actual size of the pathological sample, because ultrasound can distinguish the lesion from the desmoplastic reaction, which is the response of the surrounding tissues to tumour invasion (Fig. 4.34).

![Fig. 4.34. Uncircumscribed echo-poor lesion, measuring 11 mm, with an echogenic halo representing the desmoplastic reaction of the surrounding tissues to tumour invasion](image)

The typical ultrasound appearance of an invasive ductal carcinoma is a spiculated mass, but this feature is not specific, as it can also be associated with fibroadenomas, radial scars or fat necrosis. It may therefore be necessary to proceed to a biopsy to confirm the diagnosis. Sometimes, an invasive ductal carcinoma appears as a round or oval echo-poor mass with microlobulated or indistinct margins, with no echoic halo of a desmoplastic reaction (Fig. 4.35).

In smaller neoplasms, the margins are usually circumscribed and the structure appears more homogeneous. The neoplasm may be more echo-poor than the surrounding fibroglandular tissue or it may be isoechoic to the fat tissue; it is therefore difficult to identify these lesions in a fatty breast. The homogeneous or inhomogeneous appearance, which is well correlated with the homogeneity of the lesion on pathology, is due to the presence of sclerotic areas of fibrotic tissues (intense internal echoes) or necrotic areas (echo-poor areas or cystic components with internal echoes representing debris).

Microcalcifications are present in 40% of all breast cancers and are difficult to detect by ultrasound, especially when they are very small. Microcalcifications are more frequently visible if they are localized within a mass; outside lesions, they often look like echo-rich spots, frequently indistinguishable from the intense echoes produced by the interfaces of normal parenchyma (Fig. 4.36).
Shadowing is another distinctive feature of invasive ductal carcinoma, reported in 30–40% of cases, which correlates well with the amount of fibrous tissue within the breast cancer. Spiculated masses or diffuse cancers often alter the architecture of the surrounding parenchyma.

High-resolution transducers can reveal further ultrasound features, besides the presence of a nodular lesion, such as thickening, retraction or interruption of the skin. Subcutaneous tissue can also become thicker, and the fat tissue loses its regular structure. The Cooper ligaments and Duret crests become thicker, change their orientation and become more echoic, sometimes with posterior signal attenuation (Fig. 4.37).
Even peri-lesional ducts may appear abnormal and become stretched and sometimes moderately enlarged. Colour Doppler often shows an increase in the glandular and peri-lesional vascular supply (Fig. 4.38).

Another kind of breast tumour is **Paget disease** of the nipple, which appears as a scabby lesion of the nipple but is in fact an underlying cancer of the inner glandular tissue, frequently an intraductal carcinoma.
Invasive lobular carcinoma
This neoplasm accounts for 7–10% of all breast cancers. Lobular carcinoma is considered a riddle by even the most expert examiners. Frequently, it looks like an echo-poor lesion with ill-defined margins and minimal or no acoustic shadowing (Fig. 4.39), but sometimes it is difficult to detect even a nodular lesion within the parenchyma.

Carcinomas with a good prognosis
Mucinous carcinoma
Mucinous carcinomas account for almost 1–2% of all breast cancers. They are difficult to differentiate from benign masses as they are round or oval and have a homogeneously echo-poor pattern (Fig. 4.40).
**Medullar carcinoma**

It is difficult to distinguish between medullar and mucinous carcinomas because both are well differentiated, have a good prognosis and on ultrasound are round with an echo-poor structure and microlubulated margins (Fig. 4.41).

**Papillary invasive carcinoma**

These are circumscribed masses with lobulated margins and large calcifications, which are found inside or, less frequently, peripherally. They are frequently located beneath the nipple. As for medullar and mucinous carcinomas, malignancy should be suspected from signs such as poorly defined and incompletely circumscribed margins.

**Inflammatory breast cancer**

Inflammatory breast cancer accounts for 2% of all breast cancers, occurring most frequently during the 4th to 5th decade of a woman’s life. Clinically, it resembles mastitis, but it has a more rapid evolution, and rapid metastatic diffusion causes early death. The inflammatory state is sustained by neoplastic emboli within mammary and dermal lymphatic vessels.

On ultrasound, the skin and the derma appear thick and echo-rich. Sonography can detect echo-free tubular structures, which are congested lymphatic vessels, and echo-free lines behind the skin, which are due to interstitial liquid collection. Cooper ligaments are thickened and distorted. There may be marked, diffuse attenuation of ultrasound waves, which obscures deeper tissues. Some echo-poor nodules can be visualized and can be biopsied (Fig. 4.42).
Fig. 4.42. (a), (b) Axial and mediolateral mammographic views of the right and left breasts (CCD and OBL D: right breast; CCS and OBL S: left breast): diffuse increase in glandular density in the outer lower quadrant of the left breast, with thickening of the skin and fibrous septa. (c), (d) Ultrasound appearance of the lower (c) and inner (d) quadrants of the left breast. (c) Echo-poor nodule with blurred margins, with associated skin infiltration and diffuse attenuation of ultrasound waves that obscures the deeper localized tissues. (d) Skin thickening and subcutaneous fat oedema in the adjacent tissues of the inner lower quadrant.
Male breast carcinoma
Male breast cancer (1% of all male neoplastic disease) appears clinically as a retroareolar mass with a fibrous or wooden consistency, sometimes associated with a bloody discharge. These cancers are often invasive ductal carcinomas that do not differ morphologically from female breast cancer, except for a higher incidence of skin infiltration (Fig. 4.43).

Metastatic carcinoma
Metastasis is very rare. Melanoma is the most frequent source of metastatic breast lesions, and less frequently pulmonary, kidney and liver tumours.

Rare neoplasms
Several rare classes of breast neoplasm show ultrasound features similar to those of commoner breast tumours, with no specific differences among the subgroups. Sarcomas and lymphomas (non-Hodgkin) often show a round or irregular morphology; the only difference is their rapid growth.

Local staging
Clinical or radiological detection of a breast lesion must be followed by correct staging (TNM system) in order to identify the appropriate complete therapy (surgery, radiotherapy, chemotherapy, hormonotherapy). Ultrasound examination is useful for the detection of multifocal, multicentric or bilateral disease and in studying axillary lymph nodes.
Normal nodes are oval and have an echo-poor cortex of variable thickness (generally < 10 mm, depending on the woman’s weight) and an echo-rich hilum (fat) in which the vascular branches are located and which are visible on power Doppler.
Metastatic nodes are larger (> 1 cm), become round and show diffuse cortical thickening that displaces the lymph node hilum (Fig. 4.44).

Fig. 4.44. Metastatic axillary lymph node with a round shape, no echo-rich hilum, posterior shadowing and vascular signals only in the peripheral cortex

Sometimes, focal cortical thickening can be observed in a lymph node, but this finding does not necessarily indicate metastatic disease. Conversely, lymph node metastases may be very small (micrometastases), and the lymph node may appear normal on sonography. Therefore, all women with breast cancer should undergo biopsy of axillary lymph nodes suspected of being involved or undergo removal of sentinel nodes during surgery.