



Expanding your clinical experience

Philips ultrasound women's healthcare protocol guides

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Obstetrics

Introduction to OB/GYN 3D/4D ultrasound



Indications

Current indications

- Fetal anomalies: craniofacial malformations, skeletal malformations, neural tube defects, central nervous system malformations, abdominal wall defects, ambiguous genitalia
- Uterus and ovarian pathology: Müllerian duct anomalies, cystic tumors
- Gravid uterus: placenta previa/accreta, cornuate pregnancy, cerclage placement
- Maternal-fetal bonding
- Parent counseling

Potential indications

- Follicular evaluation
- Color 3D: placenta (invasive, velamentous cord, vasa previa)
- Remote consultation
- Volumetric data: placenta, endometrium, bladder
- Virtual endoscopy: uterus, bladder, ovarian tumors
- Volume acquisitions to replace 2D fetal screening sonograms

3D/4D imaging techniques

All ultrasound systems have controls to manage the 3D image and allow clinicians to focus on an area of interest. Each system may use different terms or have slightly different features. Terminology has not been standardized and varies among manufacturers.

The quality of the 3D rendering of MPR and volume views is based on 2D image quality. Therefore the 2D image should be optimized prior to the 3D acquisition. Optimization settings to consider are depth, gain, TGC, focal zone placement, frame rate, and the optimum transducer frequency for the anatomy being scanned. Be careful to not under-gain the image. It is helpful to have the patient suspend respiration and body movement for the 3D/4D acquisition.

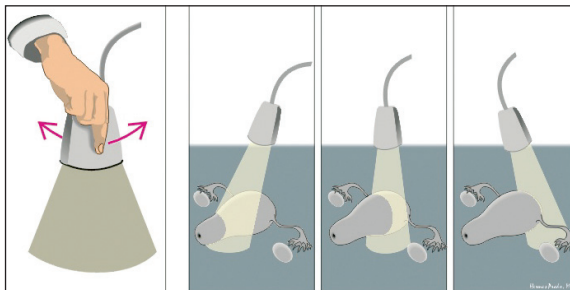


Figure 1. Manual sweeps are performed with non-electronic transducers.

Understanding the principles of 3D/4D imaging

- The pixel is the smallest unit of the two-dimensional image display. This unit defines a point in two-dimensional space with x and y coordinates. Each pixel is assigned a series of grayscale values.
- The voxel is the 3D unit representing the third dimension of the 2D pixel. The z coordinate defines the third dimension. The ultrasound system software creates the shading and rendering through the third dimension.
- The volume of data is displayed as three orthogonal planes 90° to each other. These planes are expressed mathematically as A, B, and C planes.
- The compilation of the data from three planes into a single volume of information is the inherent benefit of three-dimensional imaging. Using 3D software the user is able to obtain a single 2D sweep, and review the scanned anatomy in virtually any plane as a post-processing function.

Manual sweep 3D acquisition

- Using a regular transducer such as a curved array, sweep in a pivot (fan) motion. Maintain a steady speed while sweeping through the area of interest.
- Manual sweep acquisition requires a consistent, steady sweep speed to avoid distortions of the 3D volume. Remember, this is an un-calibrated acquisition that cannot be quantified.

Automated 3D acquisition

- The automated single sweep method uses dedicated mechanical transducers designed to produce three-dimensional images. The sonographer positions the transducer over the center of the region of interest (ROI) and begins the acquisition. The transducer is held stationary while the transducer elements automatically sweep through the 2D image.
- After the acquisition is complete the sonographer can slice or rotate through the planes sequentially and reconstruct the multiplanar (MPR) views. The reconstructed viewing planes allow visualization of anatomy that is difficult or impossible to obtain from conventional imaging.
- The MPRs are quantifiable using a variety of measurement tools. The datasets may be transferred to off-line software packages for reconstruction and measurements (Figure 2).

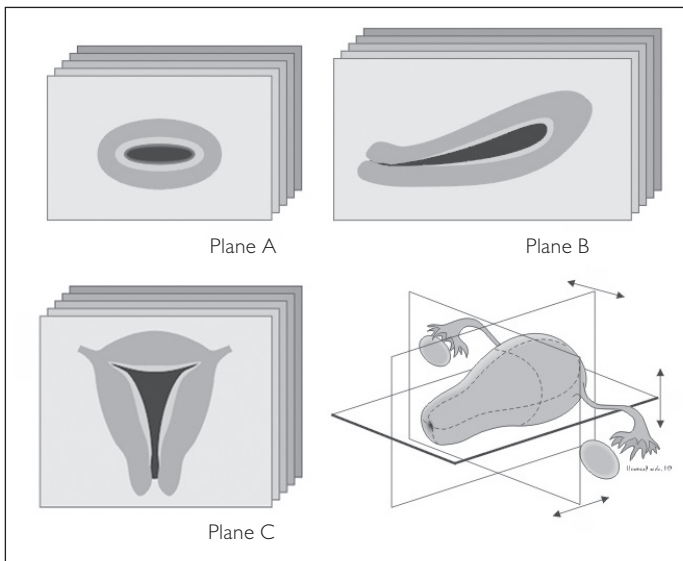


Figure 2. Orthogonal planes of the uterus.

4D acquisition

- Automated 4D acquisition is performed using a dedicated mechanical transducer. The rendered 3D image is being updated in real time during the acquisition. Using this method, fetal behavior and motion can be appreciated in real time.

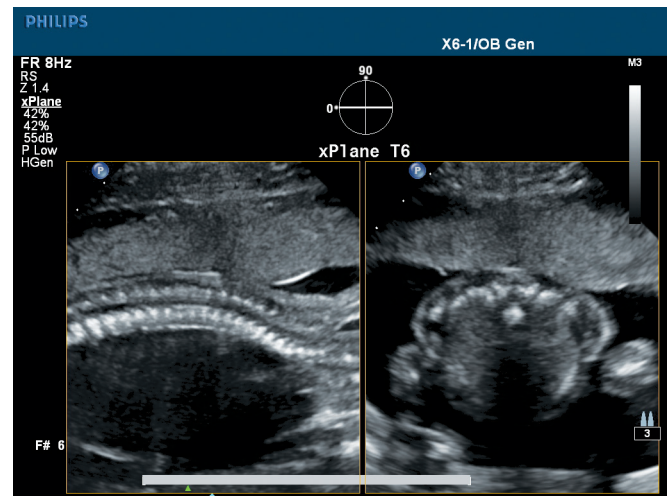
Spatio-Temporal Image Correlation (Fetal STIC)

- Single automated sweep through the fetal heart. This acquisition is a collection of many high resolution images reconstructed in both space and time to create one cycle of the beating fetal heart.
- Fetal STIC technology provides several benefits for the clinician. From a single sweep an almost infinite number of views may be created. Another benefit is the ability to visualize simultaneous MPR views to compare anatomy and pathology. STIC also allows the user to review and reconstruct the fetal heart images offline after the patient leaves.
- With xMATRIX technology, this volume can be generated in as little as two seconds, potentially increasing success rates and reducing patient scanning time.

xMATRIX technology

- xMATRIX array technology fully samples the tissue volume to create data sets providing live or retrospective access to any 2D imaging slice plane in a single acquisition.
- It offers real-time instantaneous acquisition and visualization of volume rendered anatomy at very fast volume rates.

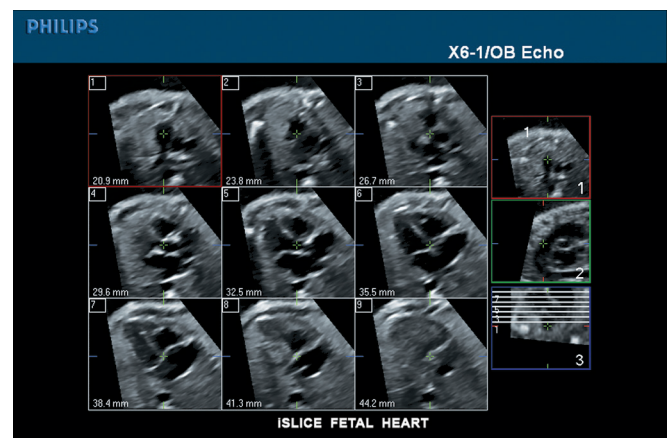
- Electronic steering aids in the focal zone of the beam slice. Ultra-thin slice imaging improves image uniformity and provides superb discrimination of micro-structures in the near, mid, and far field.
- Using xPlane, two imaging planes can be viewed simultaneously, in real time. Viewing both the transverse and orthogonal planes potentially reduces exam time and reduces transducer manipulation to potentially minimize repetitive stress injuries.



Two views of the fetal spine as seen using Live xPlane imaging.

iSlice technology

- iSlice technology allows clinicians to create cross sections of volume images, selecting the appropriate interval spacing and number of images to zero in on the area of interest.



Views of the fetal heart seen using iSlice technology.

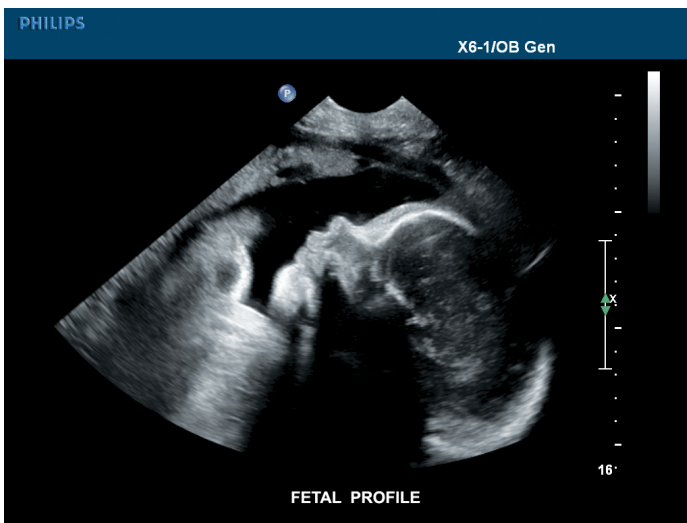
Pearls and pitfalls

Pearls

- When talking to patients, set realistic expectations about 3D. Babies do not always pose for great 3D pictures, especially of the face. Realize the limitations of the technique since high quality 3D surface images are dependent on fetal position and the amount of amniotic fluid present.
- Explain to your patient how fetal lie, location of the cord, placenta and extremities can limit visualization of the face.
- It may be helpful to use a free hand to re-position a pocket of amniotic fluid in front of the target structure.
- Keep in mind that sometimes the resultant image does not meet the expectation of the patient for a variety of reasons and be aware of the psychological implications this may bring.
- Experts who have been working with 3D for a number of years estimate acceptable 3D images are obtainable 40% of the time regardless of the type of acquisition technique used.
- The learning curve for 3D is estimated to be about one month for proficient sonographers.

Pitfalls

- Soft tissue is necessary for the most successful 3D renderings, especially for surface images of structures such as the face. The best results are usually obtained in fetuses greater than 25 weeks. In a fetus of lesser gestational age, it is less likely that a good quality surface image will be obtained.
- Body habitus plays a role in image quality in 3D just as it does in 2D. Obese or difficult to image patients usually result in less than optimal quality 3D.
- Fetal position can be a limiting factor in obtaining good quality 3D. If the area of interest is not well visualized in 2D, it will most likely not produce the best 3D rendition.
- Knowing and understanding the 2D anatomy is critical, 3D technology is not a screening technique at this time.
- Artifact recognition is very important. Any artifact visualized in the 2D image will be reconstructed in three dimensions in the 3D image. In addition, there are artifacts specific to 3D such as motion, rendering, and editing artifacts. Movement of either the patient or the fetus will result in an unusable volume. Stop the acquisition and rescan when the fetus and/or patient have stopped moving.
- Fluid volume is a key factor in 3D imaging. Lack of amniotic fluid around the desired area will result in poor quality 3D surface images. In addition, any structure located in front of the fetal face (such as the umbilical cord or placenta) may limit the quality of the surface rendering of the face. 3D does not make up for poor 2D technique or make the difficult to image patient easy to image.



Example of ideal 2D fetal profile with amniotic fluid pocket for 3D acquisition.

3D lexicon	
Acquisition	Process of sweeping, pivoting, or performing 3D or 4D that will result in volume data.
Acquisition plane	View usually shown in the top left corner of 3D display. This is the plane that the data was acquired in.
Brightness	Post-processing control that adjusts the overall brightness of the volume.
Crosshairs	On-screen tool that provides and assists in orientation throughout the MPR/volume data displays.
Data set/volume	Name given to 3D information.
Editing artifact	Artificial removal of clinically important data with improper use of trim tools. An example of this would be trimming off the fetal lips and nose to give the appearance of a cleft lip.
Freehand scanning	Scanning technique involving manual acquisition of the 3D data set producing a non-calibrated 3D data set.
Glass body rendering	Post-processing control that allows the operator to display the volume with a see-through gray setting so color information may also be seen.
Motion artifact	Any artifact in the 3D volume caused by involuntary motion. Examples of this are fetal motion, respiration, vessel/cardiac pulsations, varied sweep speed, and varied transducer pressure.
MPR views	Multiplanar reconstruction views. 2D slices displayed at orthogonal planes from the original scan plane (acquisition plane). These orthogonal views are reconstructed based on the original 2D data.
Noncalibrated data	3D data acquired without any knowledge of the spacing between the acquired 2D frames. This data cannot be calibrated and, therefore, measurements should not be attempted.
Opacity	Post-processing control that consists of a series of maps that demonstrate the voxels in shades of gray (transparency).
Orthogonal planes	MPR views that are at 90° to each other.
Rendering controls	The ultrasound unit combines all pixels in a scan line and arranges them in a voxel. Also describes post-processing group of software controls used to adjust the 3D volume display.
Rendering artifacts	Excessive threshold levels, limited region of interest, and blurring and shadowing from adjacent structures are examples of scenarios that can eliminate fetal structures from the 3D volume view. This can manifest as the appearance of absent limbs, black eyes, pseudoclefts, hole in skull, etc.
ROI	Region of interest
3D cine sequence	A variety of tools that permit the removal of undesirable areas in the 3D volume data. (Erase)
Smoothing	Rendering control used to blend voxels together.
Sweep	Motion required to acquire a 3D volume.
Texture	Post-processing control allowing adjustment of the overall surface rendering algorithm across the 3D volume.
Threshold	Post-processing control that allows the addition or subtraction of low-level echoes.
Transparency	Post-processing control that controls how "see-through" the volume is displayed. (Opacity)
Volume rendering	3D reconstruction of 2D data aimed at visualizing anatomical structures within the entire volume.
Volume view	The 3D view of the acquired data. Alternate name of 3D data.
Voxel	3D pixel

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Janet Boyd-Kristensen, RDMS, RVT, Snohomish, WA

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Guide to first trimester ultrasound exam



Indications

- Unsure dates
- Large for gestational age (LGA) or small for gestational age (SGA)
- Maternal symptoms, such as bleeding or pain, to rule out ectopic pregnancy, threatened abortion, ovarian torsion, hemorrhagic corpus luteum or molar pregnancy
- Intrauterine contraceptive device localization
- Adjunct to chorionic villus sampling

Equipment

- Vaginal probe/transducer with a frequency of 7 MHz or higher
- Abdominal probe/transducer of 5 MHz or higher
- M-mode capabilities to document viability and heart rate
- Color flow imaging (CFI) or Philips color power angio (CPA) imaging

Exam documentation

- Crown-rump length
- Average gestational sac size using measurements from three orthogonal dimensions
- Fetal heart rate
- Number of embryos/sacs

- Bilateral ovaries
- Cervix
- Uterus
- Cornea of the uterus and fallopian tubes
- Posterior cul-de-sac
- Morison's pouch in the presence of free fluid in the pelvis
- CFI or CPA of flow to suspicious masses

Pregnancy failure

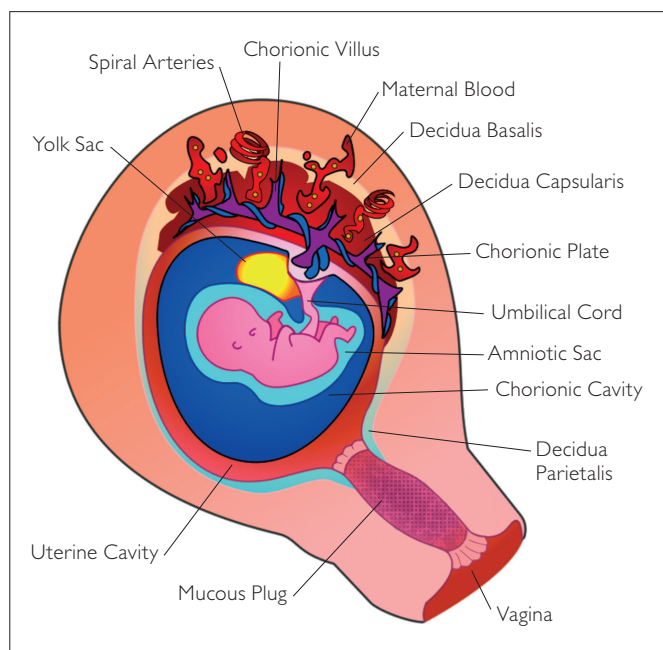
- A complete abortion (CAB) images with a uterus devoid of embryonic tissue
- Retained products of conception (RPOC) is the result of an incomplete or missed abortion (MAB).
- A gravid patient with bleeding poses a threatened abortion (TAB) and scanning may reveal a viable embryo. About 50% of the cases result in a CAB.
- A large yolk sac (7 mm or larger) or irregular shaped gestational sac lacking fetal parts raises suspicion for an anembryonic pregnancy (blighted ovum).

Ectopic pregnancy

- Any pregnancy located outside the fundal portion of the uterus.
- The ampulla is the most common area for abnormal implantation.

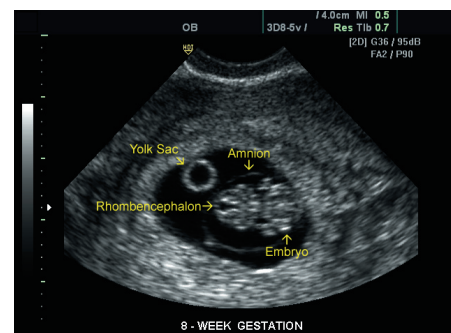
Anatomy

Embryonic



Maternal

- Uterine shape or masses
- Corpus luteum and potential adnexal masses



- Uterus lacks normal double decidual reaction, but a teardrop-shaped pocket of fluid may image in the endometrium.
- Free fluid in pelvis representing blood.
- Complex mass in adnexa or cul-de-sac may represent ruptured ectopic pregnancy.
- Coexisting extrauterine and intrauterine pregnancy (heterotopic).

Technique hints

- Gain-adjustment studies increase technical confidence through reduction of artifactual echoes. High gain obliterates small embryonic structures while low gain misses the subtle echoes that are seen with internal bleeding.
- Resolution of the small embryo, yolk sac and fetal heart activity require the highest endovaginal transducer frequency available.

- Compensate for attenuation in a structure through adjustment of time gain compensation (TGC).
- CPA helps identify rim of trophoblastic flow seen in a viable or nonviable ectopic pregnancy.

Pitfalls

- The amnion/chorion separation fuses as late as 16 weeks of gestation and may mimic a subchorionic bleed.
- Normal embryonic integument in the posterior neck can easily be mistaken for a thickened nuchal fold.
- The cystic area in the head is the normal rhombencephalon and is not to be confused with hydrocephalus.
- Midgut herniation is a normal finding, not an oomphalocele or gastrochesis.
- The hypoechoic basal plate of the developing placenta may mimic subchorionic hemorrhage.

Sonographic Signs by Week

	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11
Sonolucent fundal sac								
Corpus luteum	1-10 cm without septations							
Yolk sac			4-6 mm					
Gestational sac			Measure on three planes – 1 mm growth per day					
Crown Rump Length (CRL)								
Heart flutter			100-175 bpm					
Amnion chorion separation			Vaginal scan		Abdominal scan			
Rhombencephalon								
Head larger than body								
Parallel neural tube								
Arm and leg buds								
Midgut herniation					Echogenic mass at base of umbilical cord			
Choroid plexus						Echogenic filling of ventricles		
Cerebral falx and cranial midline								
Urine in bladder								
Fingers and toes								Vaginal scan

Clinical sources

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Guide to nuchal translucency



Background

Nuchal translucency (NT) refers to the fluid-filled area in the nuchal region of the fetus, visualized by ultrasound between 11 and 14 weeks gestation. An increased nuchal measurement indicates an increase in the chance of Down syndrome (DS), while a normal measurement indicates a reduced risk. An increased NT measurement is also associated with an increased risk of Trisomies 13 and 18, and Turner syndrome (45 XO). An NT measurement of 3 mm or more with normal chromosomes is associated with an increased chance of certain birth defects, especially cardiac defects and genetic syndromes such as arthrogryposis.

The nuchal translucency normally increases with gestational age, therefore, when screening for fetal Down syndrome, biometric cut-offs are not recommended. Rather, the NT should be interpreted in the context of gestational age (GA) specific medians and the woman's background risk, which is determined by her age, gestational age and past history. This is known as the NT-adjusted risk.

Of the various software packages available for calculating the NT-adjusted risk, the most widely used is that licensed to individuals and centers certified by the Fetal Medicine Foundation (FMF), United Kingdom, in the theoretical and practical aspects of NT screening. To become certified in NT scanning, sonographers must submit a logbook of 50 images for audit by the Fetal Medicine Foundation and agree to comply with an ongoing quality assurance program.

Nuchal translucency screening (NTS) for fetal Down syndrome should optimally be offered in the context of a comprehensive prenatal screening program that provides pre- and post-ultrasound counseling, risk interpretation and follow-up, including prompt access to invasive testing where indicated. For women with normal chromosomes and an increased NT measurement between 11 and 14 weeks, fetal echocardiography and a detailed Level 2 ultrasound scan should be offered.

Technique

Equipment

The scan should begin transabdominally. However, if the patient's body habitus precludes satisfactory visualization, a transvaginal scan should be done. To ensure uniformity among sonographers, the following guidelines for measuring the nuchal translucency, as defined by the FMF, London, UK, are recommended:

- The NT examination should be performed with a high-resolution, real-time scanner. The frequency range of the transducer should be between 7 MHz and 2 MHz depending on patient body habitus.
- Indications for doing a transvaginal ultrasound are poor visualization, inability to measure NT by the transabdominal method, or suspicion of nuchal or extra-nuchal abnormality. A transvaginal scan may allow better characterization of the NT and evaluation of the remaining fetal anatomy.
- The ultrasound system should have cine review capability and read/write zoom.
- The system should have sufficient image quality to maintain high resolution when the image is enlarged to occupy at least two-thirds of the screen.
- The calipers must be able to discriminate below 1 mm, and should maintain the crossbar appearance when measuring increments below 1 mm.

Patient preparation

The patient should have counseling regarding the role of the NT measurement as a screening test for chromosome abnormalities before undergoing the ultrasound scan. A full bladder is not necessary, although some liquid in the bladder is preferred.

Measurements

At what gestational age should the nuchal translucency be measured?

The NT measurement is a component of a complete first trimester scan and should be performed between 11 and 14 weeks (CRL 45-84 mm). If the fetus measures outside this range, the NT can still be measured, however, the NT-adjusted risk assessment (using the FMF software) cannot be performed.

How is the nuchal translucency measured?

A sagittal plane of the fetus, as used for measurement of a CRL, should be obtained. The ultrasound beam should be directed perpendicularly to the long axis of the spine. Oblique and coronal views should be avoided. When the image plane is correct, the NT appears as two white lines with a thin layer of fluid between them. The measurement can be obtained anywhere between the occiput and mid-thoracic area, however, the nape of the neck is preferred. The entire CRL does not need to be visualized for the measurement to be performed.

The magnification should be such that the fetus occupies at least three-quarters of the image. Considering the results are in millimeters, this provides more finite control of the calipers and improved accuracy.

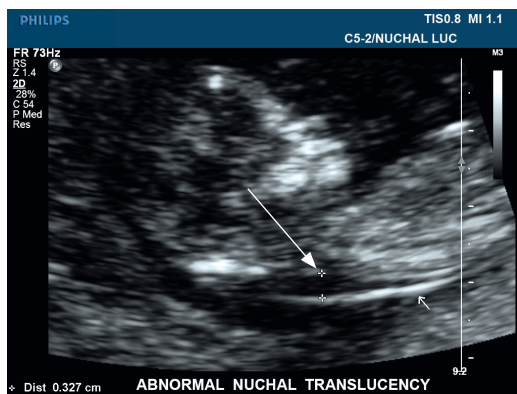


Image 1. Abnormal nuchal

The maximum thickness of the subcutaneous translucency, between the skin and soft tissue overlying the cervical spine, should be measured by placing the calipers on the lines as shown in Image 1.

Note that the cross bar of the caliper should be flush with the inner aspect of the line with only the straight end of the caliper within the lucency. At least three measurements should be taken and the best/maximum reported.

Multiple gestations

Nuchal translucency screening offers an exciting new option for prenatal screening in multiple pregnancies. Prenatal counseling of multiples is, however, contingent upon accurate ultrasound determination of chorionicity.

Zygosity and chorionicity

Dizygotic (fraternal) twins, which account for two-thirds of all twins, are always dichorionic diamniotic (DCDA). The placentas can either be adjacent to each other or on opposite sides of the uterus. When the placentas are next to each other, the inter-twin membrane is thick and a triangular piece of placental extension known as the lambda sign may be visible on ultrasound. The remaining one-third of twins are monozygotic (identical). When splitting of the single egg mass occurs in the first three days, the placentation will be DCDA; if it occurs after day three, there are common blood vessels joining the two placentas that therefore act as if they are one (monochorionic/MC). In these cases, the intertwin membrane is thin and there is no lambda sign at the junction between the membrane and the placenta (T-junction). Twin-to-twin transfusion syndrome (TTS) is a complication of some MC gestations with polyhydramnios in one fetus and oligohydramnios in the other. Severe cases are associated with a high risk of death and/or handicap in survivors. TTS does not occur in dichorionic gestations.

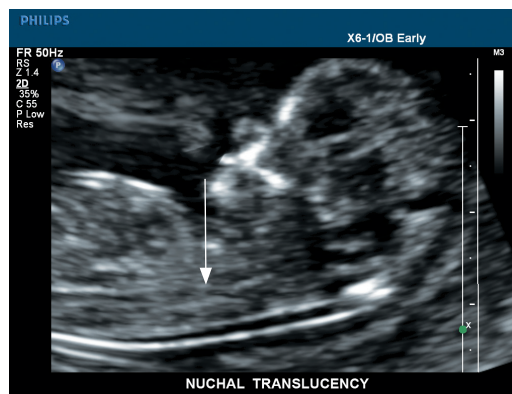


Image 2. Normal nuchal

Nuchal translucency measurement in twins

- In dichorionic twins, the NT is measured in each fetus. This measurement is combined with maternal age to calculate the risk for trisomies in each fetus. If the risk of at least one of the fetuses is more than the predetermined cut-off, then invasive testing (chorionic villus sampling or amniocentesis) is offered.
- In monochorionic twins, the number of cases examined is still too small to draw definite conclusions as to whether, in the calculation of risk of trisomy 21, the NT of the fetus with the largest or the smallest measurement (or the average of the two) should be considered. Increased NT in one of the fetuses, or discordance in NT by more than 1 mm, should prompt a search for alternative causes such as twin-to-twin transfusion syndrome.

Pearls and pitfalls

- If a patient is difficult to visualize, perform a transvaginal scan.
- If a nuchal translucency abnormality is suspected, do a transvaginal scan to characterize the NT lesion. Perform a detailed scan to look for other abnormalities.
- The umbilical cord may be wrapped around the fetal neck in 5–10% of cases and this finding may produce a falsely increased nuchal translucency. Cord loops are seen as multiple echoes in the nuchal region and can be documented by color Doppler. In such cases, the measurements of nuchal translucency above and below the cord are different and, in the calculation of risk, it is more appropriate to use the smaller measurement. If a reliable measurement cannot be obtained, the patient should be asked to return for another scan.
- Always obtain transverse views of the fetal neck to avoid missing lateral hygromas or other abnormalities.

Clinical sources

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Guide to second and third trimesters ultrasound exam



Indications and patient history

- Estimation of gestational age and evaluation of fetal growth
- Vaginal bleeding of undetermined etiology
- Determine fetal presentation
- Suspected multiple gestation
- Adjunct to amniocentesis
- Uterine size/clinical dates discrepancy
- Pelvic mass
- Suspected fetal death
- Biophysical profile evaluation for fetal well-being
- Suspected polyhydramnios or oligohydramnios
- Suspected abruptio placenta
- Adjunct to external version from breech to vertex presentation
- Estimation of fetal weight
- Abnormal screening biochemical test for fetal anomaly
- Rule out congenital anomalies
- Follow-up observation of identified fetal anomaly
- Follow-up evaluation of placental location for identified placenta previa
- History of previous congenital anomaly
- Serial evaluation of fetal growth in multiple gestation
- Suspected hydatidiform mole
- Adjunct to cervical cerclage placement
- Suspected uterine abnormality

Anatomy

Technique

- Utilizing the highest possible frequency transducer, perform a survey scan in longitudinal and transverse planes determining fetal lie

Fetal number, fetal presentation and fetal life assessment

- Evaluate for congenital anomalies (Follow protocol as defined by AIUM 2nd/3rd trimester examination.)
- Document number of gestations
- Determine fetal viability/document cardiac rate
- Document fetal presentation (vertex, breech or transverse)
- Determine right and left sides of fetus

Placental size, appearance, location and texture

- Evaluate the size, texture, location and retroplacental structures
- Abnormal thickness larger than 5 cm: assess for maternal diabetes, Rh immunization factor, maternal anemia and multiple gestations
- Chorionic plate: assess the portion toward the inside of the sac touching the amniotic membrane
- Basilar plate: assess the portion on the outside touching the uterus for correct placental location
- Placenta has a fairly constant echotexture throughout the gestational period; with age the placenta will demonstrate hypoechoic and echogenic areas
- Document placental location in longitudinal and transverse planes and its relationship to the cervix. Placenta previa may be associated with vaginal bleeding and may require a cesarean section delivery

Placental grading

- Grade 0: smooth chorionic plate; placental substance is free of hyperechoic areas
- Grade 1: chorionic plate shows some subtle indentation with a few scattered bright echoes within the placenta
- Grade 2: chorionic plate has comma-like indentations on the surface
- Grade 3: chorionic comma-like densities continue through the placental substance; the basilar plate has numerous hyperechoic areas

Umbilical cord

- 3 vessel cord: contains 2 arteries and 1 vein
- 2 vessel cord: contains 1 artery and 1 vein, and may be associated with other fetal anomalies
- Cord insertion into the fetal abdomen should be assessed for abdominal wall defects
 - Gastroschisis: positioned to the right of the fetal abdominal cord insertion; open abdominal wall with small bowel protruding; other anomalies usually are not present
 - Omphalocele: centrally placed, involving the fetal abdominal cord insertion; the bowel and liver may be protruding; often other anomalies are associated

Lower uterine segment

- Assessing the cervix is important for identifying placenta previa as well as for identifying cervical incompetence
- Sonographic approaches: transabdominal, translabial and transvaginal
- Normal cervical length: larger than 3 cm; look for funneling of the internal os

Amniotic fluid

- First and second trimester fluid usually anechoic
- Third trimester: floating particles may be normal vernix
- Fluid volume increases up to the 28th week and decreases thereafter
- Amniotic Fluid Index (AFI)
 - Divide maternal abdomen into four quadrants
 - Keep transducer perpendicular with the floor
 - Maintain light pressure with transducer
 - Measure greatest vertical pocket (anterior to posterior) in each quadrant
 - Do not measure fluid where loops of cord are present; utilize color or power Doppler to obtain a more accurate fluid volume assessment
 - Add all quadrants together
- Polyhydramnios
 - AFI 20-24 cm or larger or single vertical pocket 8 cm or larger
- Oligohydramnios
 - AFI 5-8 cm or smaller
 - At 16-34 weeks AFI 8 cm or smaller is termed oligohydramnios
 - Beyond 34 weeks fluid is decreasing; at least a 2 cm x 2 cm pocket should be seen

Gestational age measurements

Assess by measuring the biparietal diameter (BPD), head circumference (HC) and femur length (FL); abdominal circumference (AC) is necessary to evaluate fetal weight and growth.

- BPD: measured at the level of the thalami and cavum septum pellucidum. Most reliable measurement is done by placing the calipers at the anterior outer edge of the skull and the inner edge of the skull on the opposite side.
- HC: measured at the same level as the BPD. Can be calculated by using BPD and OFD (occipito-frontal distances). The OFD is measured outer edge to outer edge of the skull. HC can also be obtained from an ellipse measurement or continuous trace method.
- FL: routinely measured from 14 weeks

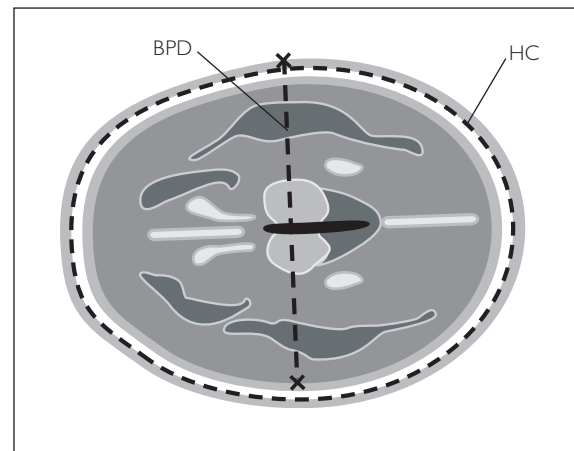


Figure 1. Biparietal diameter (BPD) and head circumference (HC)

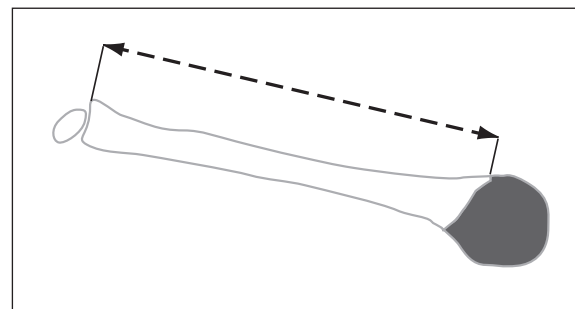


Figure 2. Femur length (FL)

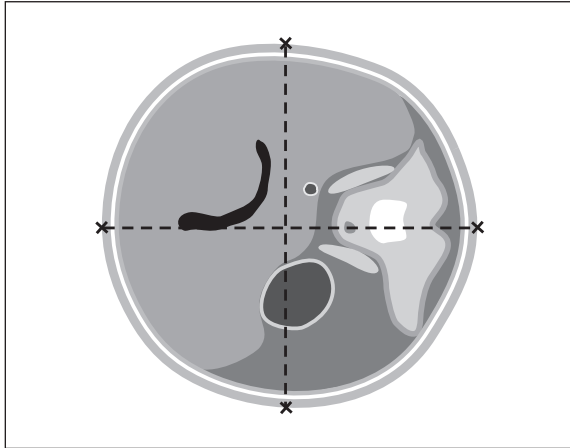


Figure 3. Abdominal circumference (AC)

- AC: measured at the level of the stomach where the umbilical vein turns into the portal sinus forming the shape of a “J”. The umbilical vein should not be seen at the abdominal wall, as this plane is too oblique. Calipers should be placed on the outer abdominal wall using an ellipse, continuous trace or two perpendicular distances.

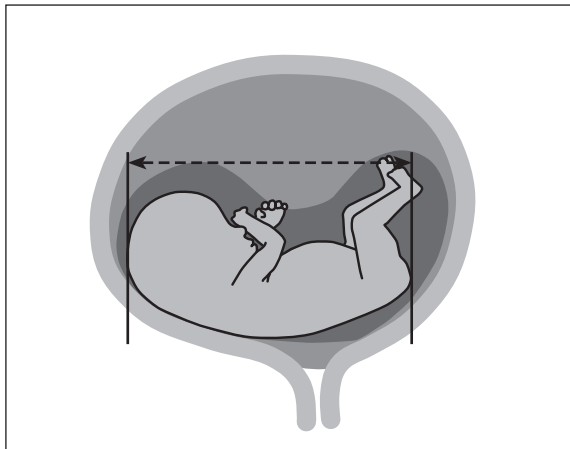


Figure 4. Crown-rump length (CRL)

Routine fetal measurements to determine gestational age

- First trimester: chorionic sac, CRL
- Second and third trimesters: BPD, HC, AC, femur

Additional nomograms to assist in determining fetal age/growth or anomalies

- Humerus
- Radius
- Ulna
- Tibia
- Fibula
- Clavicle
- Scapula
- Foot
- Ear
- Orbital distance (OD)
- Inner orbital distance (IOD)
- Outer orbital distance (OOD)

Ratios

- CI: cephalic index; normal range 70-86%; below 70 would be dolicephalic, above 86 would be brachycephalic; formula $CI = BPD / OFD \times 100$
- HC/AC: as the abdomen becomes larger relative to the head, the ratio becomes smaller, which indicates possible macrosomia. As the abdomen becomes smaller relative to the head, the ratio becomes larger, possible asymmetric IUGR (intrauterine growth restriction).
- FL/BPD: helps to determine IUGR or detect head or femur pathology
- FL/AC: helps to determine IUGR or detect abdominal or femur pathology

Obtaining fetal weight

- Accurate abdominal circumference is necessary
- BPDa (corrected BPD): should be used in the fetal weight formula with dolicephalic or brachycephalic shaped heads

Fetal anatomy survey for malformations

Fetal head and spine

- Assess fetal head shape and echogenicity, abnormal shape such as a lemon head may be indicative of spina bifida, decreased echogenicity may be indicative of skeletal dysplasias



Figure 5. Lateral ventricles

- Lateral ventricles: measure the ventricle at the atria (posterior portion), and the ventricle farthest from the transducer; normal measurement is less than 10 mm

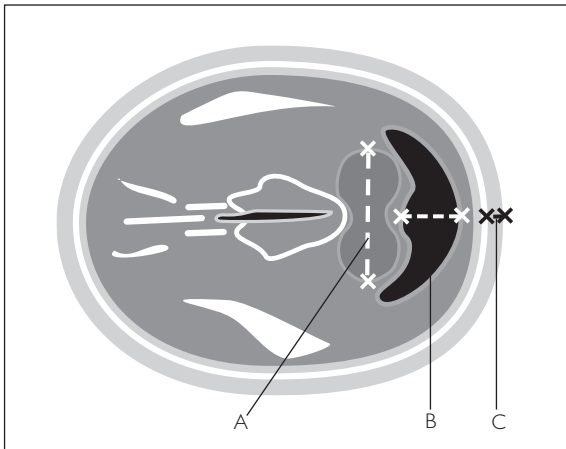


Figure 6. Cerebellum

- Cerebellum: measurement matches gestational age between 14-20 weeks. The banana sign is an abnormal cerebellar shape that is indicative of Arnold-Chiari syndrome. Figure 6, A
- Cisterna magna: space between the vermis of the cerebellum and the inner table of the occipital bone; normal measurement 2-10 mm. Figure 6, B
- Nuchal fold: done between 16-20 weeks. Measure outer table of skull to outer skin; normal measurement is less than 6 mm. Figure 6, C
- Fetal profile: assess relationship of forehead to nose and lips, and presence of nasal bone to rule out Down syndrome
- Fetal nose and lips: assess palate and lip for cleft
- Fetal orbits: assess normal size, shape and presence of the lens
- Spine and neck: assess in transverse and sagittal planes

Fetal chest

- Acquire the 4-chamber heart view by obtaining a transverse thorax cut, which can rule out 75% of congenital heart defects
- Assess heart size in comparison to the chest (no more than 1/3 in area and 1/2 in perimeter)
- Compare symmetry of right and left sides of heart
- Assess heart axis: apex should be approximately 45 degrees to the left; foramen ovale shunts from right to left
- Assess the septum: interventricular septum should be continuous; atrial septum has the foramen ovale with atrial septa above and below it
- Assess the heart for normal cardiac rhythm; place the M-line through an atrium and ventricle to obtain heart rate
- Assess fetal lung: echotexture more echogenic than liver

Fetal abdomen

- Stomach: normally visualized at 14 weeks on fetal left side
- Fetal bowel: small bowel is more echogenic than fetal liver. The centrally located small bowel may peristalsis. Large bowel is in the periphery of the abdomen and is more hypoechoic than the small bowel
- Kidneys: on either side of the spine and mid-abdomen; oval, with hypoechoic outer portion and slightly echogenic inner portion; renal pelvic dilatation of less than 4 mm is physiologic
- Urinary bladder: present and within abdominal wall
- Umbilical cord insertion: located at the anterior abdominal wall

Fetal extremities

- Assess relationship of feet to the lower leg, hand to lower arm, and opening of hands
- Account for 12 long bones

Assessing multiple gestations

Risks and complications

- Higher rate of mortality than singleton pregnancy
- Increased risk of growth retardation, premature delivery, placental insufficiency, preeclampsia, maternal bleeding or prolapsed cord

Anatomy

- Two types of twins: dizygotic (arising from two separate fertilized ova) and monozygotic (arising from one fertilized ova)
- Dizygotic twins each have their own placenta, chorion and amniotic sac (dichorionic, diamniotic)
- Monozygotic twins result in identical twinning and may be diamniotic

Technique

- Assess each fetus in its entirety as one would a singleton
- Baby "A" is the fetus closest to the cervix (presenting fetus)

Pearls and pitfalls

- Transvaginal approach
 - Accurately evaluates cervix
 - Ability to acquire BPD if fetal head is low lying
 - Vertex presentation: assess fetal head anatomy
 - Breech presentation: assess distal spine and genitalia
- Translabial approach provides ability to evaluate cervix or low-lying placenta
- With maternal obesity, try imaging through the umbilicus with a small footprint transducer
- When imaging the fetal heart, more contrast will better assess heart structure. Try Philips SonoCT imaging, harmonics, decreasing dynamic range or compression, and grayscale curves. Using Philips Chroma color scales also may aid in a more pleasing contrast resolution.
- Utilize a single focal zone
- Assessing multiple gestations
 - May be diagnosed at 6 weeks gestation
 - Be aware of imaging artifact, mirror image artifact, or fluid collection mimicking a gestational sac
 - Utilize a systematic approach during your survey scan keeping the transducer perpendicular to the floor while assessing fetal number and position

Clinical source

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Consultant

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Guide to biophysical profile ultrasound examination



A biophysical profile (BPP) is a real-time ultrasound observation and scoring of four parameters to help determine fetal well being. A non-stress test (NST), which measures fetal heart rate acceleration in response to fetal movement, is a non-imaging component often included in the BPP.

Indications

- Post-dates
- Maternal diabetes
- Intrauterine growth restriction (IUGR)
- Small-for-dates
- Premature rupture of membranes (PROM)
- Maternal hypertension
- Mother reports a decrease in fetal activity
- Maternal drug use

Technique

The fetus is observed using real-time ultrasound for a period of thirty (30) minutes.

- All fetal motor behavior may be seen at 16 weeks and increases in frequency with gestational age.
- Factors that may change the biophysical profile score include hypoxemia, drugs and fetal sleep cycles.
- Some clinicians advocate preparing the patient by having them eat within an hour of the BPP to decrease the likelihood of false positive results. This also ensures greater reproducibility of findings.

Variables to assess fetal well-being

- Fetal breathing movement – Fetal breathing is described as an inward movement of the chest wall with an outward movement of the abdominal wall. One may assess the kidneys for a longitudinal movement as well. There must be at least one episode lasting for 30-60 seconds during a 30-minute period.
- Fetal movement – Three movements consisting of body rolls, head rolls or spine flexion in a 30-minute period.

- Fetal tone – One episode of flexion of upper or lower extremity, or opening/closing of fist, flexion/extension of fetal neck.
- Amniotic fluid volume
 - Pocket 2 cm x 2 cm or larger, or
 - An amniotic fluid index (AFI) larger than 5 cm
- NST (non-stress test)
 - Performed prior to or following the BPP using a fetal heart rate monitor
 - Non-ultrasound evaluation which indicates fetal heart rate reactivity
 - Normal would entail two or more heart accelerations of at least 15 beats per minute in amplitude, and for 15 seconds in duration

Interpretation

- Many labs do not perform the NST as part of their biophysical profile; therefore, the total possible score would be 8 instead of 10.
- Score of 8 or 10 is considered normal.
- Score of 6 is equivocal and indicates that the biophysical profile should be repeated within 12 hours.
- Score of 4, 2 or 0 is indicative of fetal compromise and delivery of the fetus should be considered.

Pearls and pitfalls

- Fetal stimulation
 - Fetus may be sleeping and not very active
 - Maternal body position may be altered to induce fetal activity
 - Some labs allow probing with the transducer
 - Some labs use vibroacoustic stimulation (buzzer) to evoke startle response
 - Some labs do not allow any fetal stimulation
- Acquire a non-frozen image of a transverse fetal abdomen with parts of the legs and or arms in view. This image will allow one to observe fetal tone, movement and breathing all at the same time.

Measurements – two methods of scoring

Method one: Prominent in North America

For each passing or normal variable, a score of two is given. For each abnormal variable, a score of zero is given.

Fetal movements	Score 2: 3 or more body rolls, head rolls, or spine flexions within 30 minutes Score 0: less than 3 body rolls, head rolls, or spine flexions within 30 minutes
Fetal breathing movements	Score 2: 30-60 seconds duration of fetal breathing movement within a 30-minute period Score 0: less than 30 seconds duration of fetal breathing movement within a 30-minute period
Fetal tone	Score 2: One flexion and extension of an extremity or an opening and closing of the hand within a 30-minute period Score 1: At least one flexion and extension of an extremity or one flexion and extension of the spine within 30 minutes Score 0: No flexion or extension of an extremity within a 30-minute period
Amniotic fluid volume	Score 2: At least one 2 cm x 2 cm pocket of amniotic fluid or an AFI of at least 5 cm Score 0: Largest pocket of amniotic fluid is less than 2 cm x 2 cm, or an AFI less than 5 cm
Non-stress test	Score 2: Normal baseline fetal heart rate is 110-160 bpm, with two accelerations of 15 bpm for 15 seconds within 30 minutes Score 0: Baseline heart rate less than 110 bpm or greater than 160 bpm; or less than two accelerations of 15 bpm for 15 seconds

Method Two: Prominent in Europe

Each variable including the placental grading receives a score of 0, 1 or 2

Fetal movements	Score 2: At least three body or limb movements within 30 minutes Score 1: One or two body or limb movements within 30 minutes Score 0: No body or limb movements within 30 minutes
Fetal breathing movements	Score 2: Fetal breathing movements that are 60 seconds in duration within 30 minutes Score 1: Fetal breathing movements lasting 30-60 seconds in duration within 30 minutes Score 0: No fetal breathing movements, or breathing movements that last less than 30 seconds within 30 minutes
Fetal tone	Score 2: At least one flexion and extension of an extremity, as well as one flexion and extension of the spine, within 30 minutes Score 1: At least one flexion and extension of an extremity, or one flexion and extension of the spine, within 30 minutes Score 0: Extremities are in extension with no return flexion movements to their original positions; hands are open
Amniotic fluid volume	Score 2: At least one 2 cm x 2 cm pocket Score 1: A pocket of fluid measuring less than 2 cm but greater than 1 cm Score 0: Largest pocket of fluid measuring less than 1 cm in two perpendicular planes
Non-stress test	Score 2: 5 or more fetal heart rate accelerations of at least 15 bpm in amplitude and at least 15 seconds in duration within a 20-minute period Score 1: 2-4 fetal heart rate accelerations of at least 15 bpm in amplitude and at least 15 seconds in duration within a 20-minute period Score 0: 0-1 fetal heart rate accelerations of at least 15 bpm in amplitude and at least 15 seconds in duration within a 20-minute period
Placental grading	Score 2: Placental grading of 0, 1 or 2 Score 1: Placenta is difficult to grade due to a posterior location Score 0: Placental grading of 3

Clinical sources

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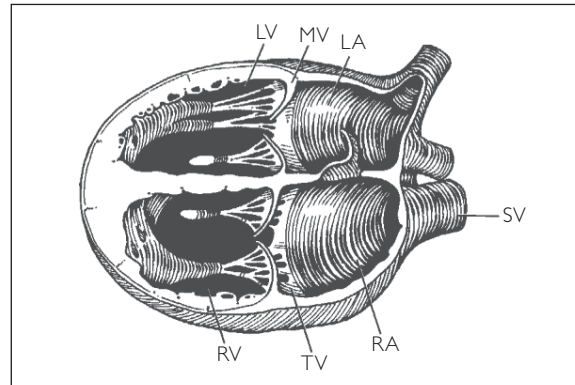
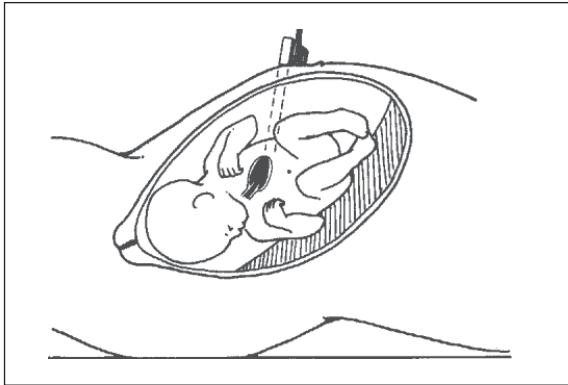
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Guide to fetal echocardiography

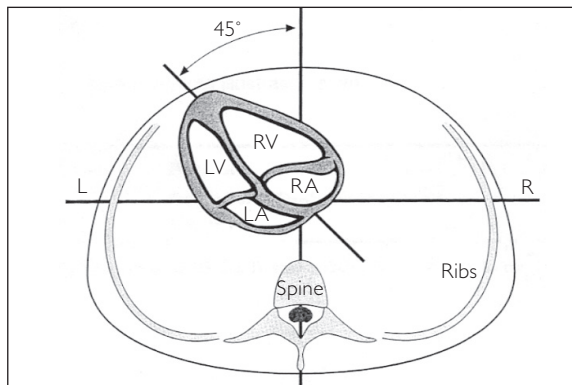


Standard Fetal echocardiographic views



First – determine situs

- Identify fetal position.
- Locate fetal stomach and other abdominal organs.
- Verify relationship of fetal stomach to fetal heart – apex of heart should be to the left.

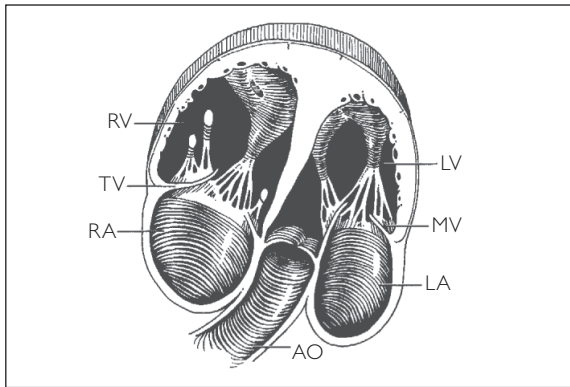


Third – four-chamber view

- Obtain a four-chamber view. Locate and verify:
- An intact interventricular septum
- Right and left atria approximately the same size
- Right and left ventricles approximately equal size
- Free movement of mitral and tricuspid valves
- Foramen ovale flap in left atrium
- Insertion of the tricuspid valve on the interventricular septum closer to the cardiac apex than the insertion of the mitral valve

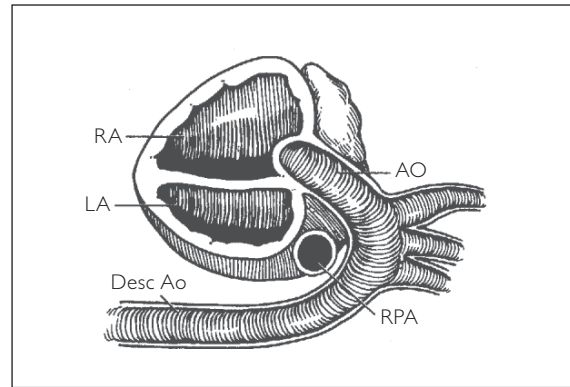
Second – fetal cardiac axis

- Obtain a cross-section of the chest at the level of the four-chamber view of the heart.
- Segment and evaluate by drawing a line from the spine to the anterior chest wall to divide the chest into equal halves.
- The cardiac axis is the angle created between the interventricular septum and this line.
- The normal axis lies at a 45° angle to the left of the midline.



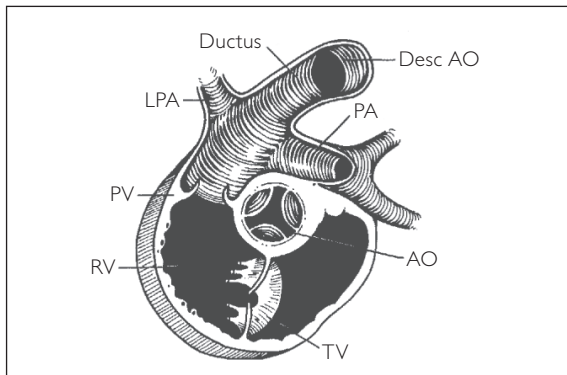
Fourth – long axis left ventricular outflow tract (five-chamber view)

- Obtain the long axis view of the left ventricular outflow tract. Locate and verify:
- Intact interventricular septum
- Continuity of the ascending aorta with mitral valve posterior and interventricular septum anterior



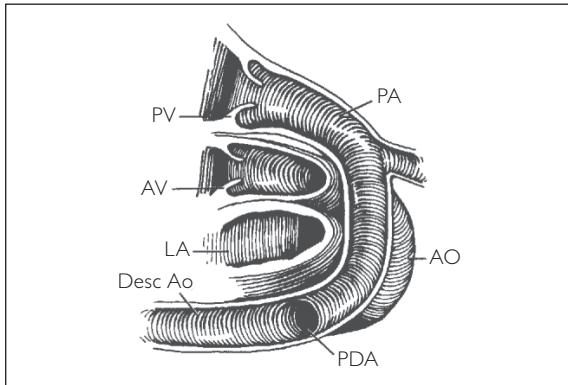
Sixth – aortic arch

- Locate aortic arch and verify that the aorta exits from the posterior (left) ventricle. (Not shown.)
- Verify that the three head and neck vessels branch from the aorta.



Fifth – short axis of great vessels

- Obtain the short axis view of the great vessels. Locate the pulmonary artery, which should exit the anterior (right) ventricle and bifurcate.



Seventh – pulmonary artery and ductus arteriosus

Locate the descending aorta; confirm continuity of the ductus arteriosus with the descending aorta.

Risk factors

Familial risk factors

- History of congenital heart disease
 - Previous sibling
 - Paternal
- Examples of Mendelian syndromes that include congenital heart disease
 - Noonan
 - Tuberous sclerosis

Maternal risk factors

- Congenital heart disease
- Cardiac teratogen exposure
 - Lithium carbonate
 - Alcohol
 - Phenytoin
 - Valproic acid
 - Trimethadione
 - Carbamazepin
 - Isotretinoin
 - Vitamin A
- Maternal metabolic disorders
 - Diabetes mellitus
 - Phenylketonuria
 - Methylene tetrahydrofolate deficiency
- Severe polyhydramnios

Fetal risk factors

- Extracardiac anomalies
 - Chromosomal
 - Anatomic
 - First trimester nuchal translucency
- Fetal cardiac arrhythmia
 - Irregular rhythm
 - Tachycardia (greater than 200 BPM) in absence of chorioamnionitis
 - Fixed bradycardia
- Non-immune hydrops fetalis
- Suspected cardiac anomaly on basic (Level I) scan

Pearls and pitfalls

- When extracardiac anatomy is relatively clear, failure to see a normal four-chamber view in an otherwise unremarkable general fetal scan suggests a strong risk factor for major congenital heart disease.
 - View where all four chambers, ventricular and atrial septum, foramen ovale and flap, tricuspid and mitral valves, and the pulmonary veins are easily visualized.
 - When carefully obtained, screening four-chamber views should detect 50-80 percent of major congenital heart disease. However, significant anomalies may be missed.
 - If any of the risk factors listed are present, a fully detailed study should be offered to the parents.
 - Consider outflow tracts of the heart.
- When a cardiac anomaly is suspected, the first step is to evaluate all parts of the heart and great vessels.
 - Many cases of fetal heart disease are quite complex. Whether or not color and pulsed Doppler are a routine part of all fetal echocardiograms, evaluation of flow patterns is important to confirm the diagnosis and help provide prognostic information for the parents.
 - The entire fetus should be carefully examined with a comprehensive fetal anatomy survey (Level II) because extracardiac anomalies are often present.
 - A karyotype should always be offered to the parents, as chromosome abnormalities are present in 15 percent of fetuses with isolated heart disease, and double that number if extracardiac anomalies are present.
- When viewing the interventricular septum, the normal thinning of the septum below the atrioventricular valves may give an artifactual appearance of septal defect if seen from the apex of the heart (i.e., parallel to the septum). This can be excluded by looking perpendicularly to the septum.
- To obtain the left ventricular outflow tract (LVOT), or long axis view, tilt the transducer slightly toward the fetal head from a four-chamber view.
- To obtain the origin of the pulmonary artery, or right ventricular outflow tract (RVOT), tilt slightly farther cephalad and anterior.
- When viewing the long axis, a slightly anterior view may include the pulmonary artery in the tomogram and cause apparent dropout above the aortic valve. If there is an overriding aorta (anterior ventricular septal defect as seen in tetralogy of Fallot or double outlet right ventricle), the defect will be below the aortic valve.
- M-mode echocardiography can be useful for documenting fetal arrhythmias and if precise measurements of cardiac anatomy are desired.
 - Careful placement of the cursor is required for accurate measurements.
 - If septal thickness is measured in diabetics, it must be obtained directly below the atrioventricular valves. Normal is less than 5 mm late in the third trimester when diabetic hypertrophic cardiomyopathy may occur.

Clinical source

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Guide to Doppler in the gravid pelvis



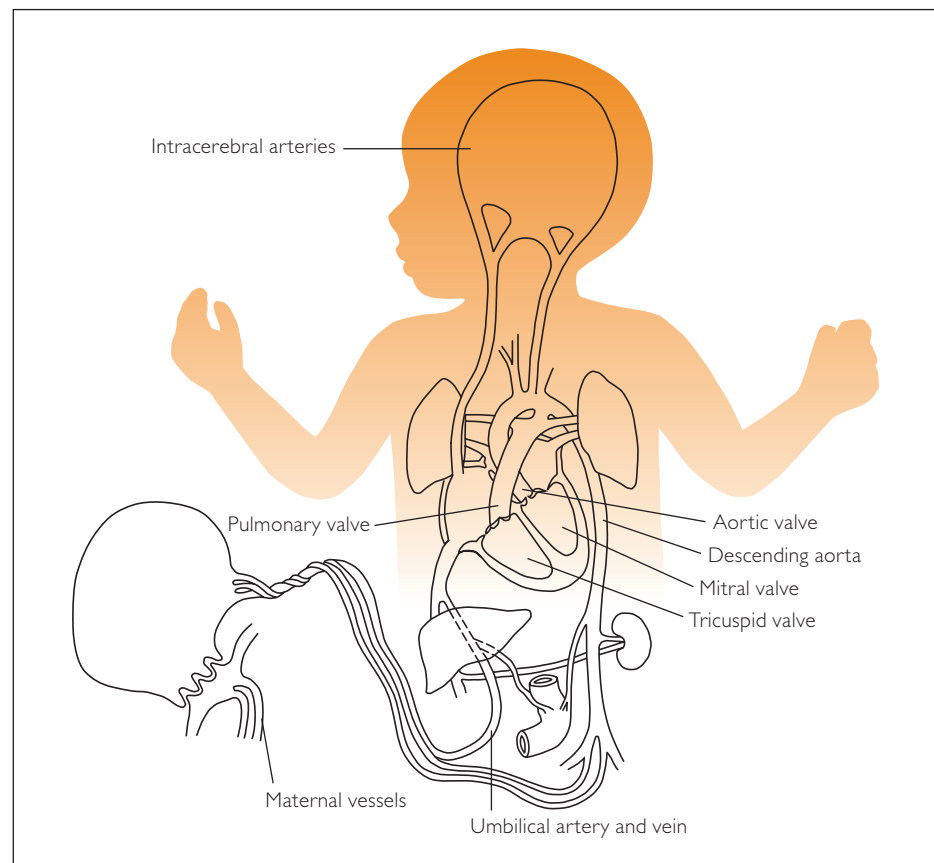
Conventional 2D ultrasound has long been the standard imaging modality of the gravid pelvis. The addition of spectral Doppler, color Doppler, and Philips color power angio (CPA) imaging has provided an excellent adjunctive tool in the ultrasonic evaluation of the pregnant patient.

Color Doppler can be used to assist in the identification of vascular architecture, detection of vascular pathology and visualization of blood flow changes associated with physiologic processes and disease states.

Spectral Doppler displays velocity or frequency data, and allows qualitative and quantitative blood flow measurements. Color Doppler improves the accuracy of sample volume placement when acquiring spectral Doppler data.

The ability to access blood flow information in the gravid patient is a powerful adjunctive tool in the evaluation of maternal and fetal well being. Doppler is most useful in high-risk populations to identify fetuses at increased risk.

Due to the tortuous nature of many of the vessels typically interrogated in the gravid pelvis, absolute velocity data is not accurately obtained. The use of arterial indices was adopted, as they are angle-independent methods that provide semiquantitative data relative to the prediction of fetal compromise. The indices discussed in this protocol guide reflect downstream resistance



Indications for gravid Doppler exam

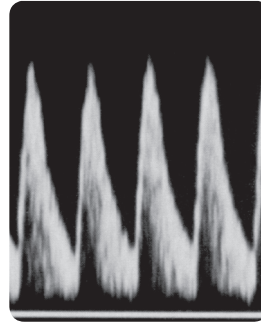
- Hypertension (HTN)
- Diabetes
- At risk for fetal anomalies
- Multiple gestations
- Fetal hydrops
- Post-term pregnancy
- Cardiac anomalies
- Oligohydramnios
- Polyhydramnios
- Twin-to-twin transfusion

Doppler measurements and indices

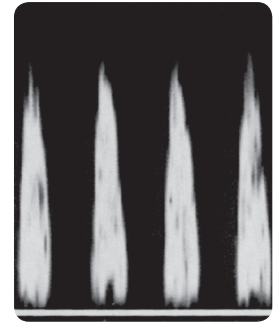
- Systolic/diastolic ratio (S/D) = S/D
- Pulsatility index (PI) = $(S-D)/\text{Mean}$
- Resistive index (RI) = $(S-D)/S$
- Legend: S = systole; D = diastole

Definitions

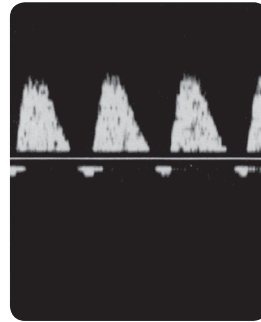
- Mean – calculated by ultrasound system software and represents the average flow velocity within a cardiac cycle
- Systole – the contraction phase of the cardiac cycle
- Diastole – the relaxation period of the cardiac cycle
- Diastolic notching – an abrupt and temporary dip towards the baseline, occurring during the diastolic phase of the waveform



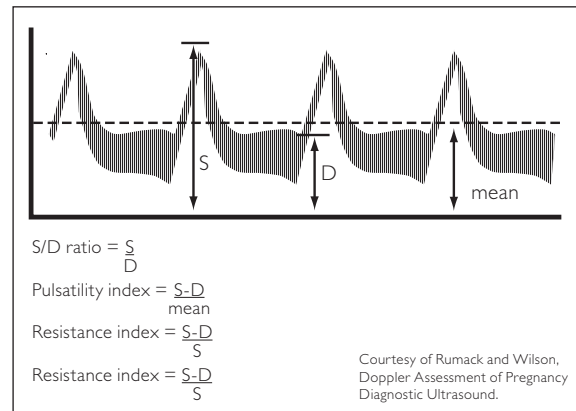
Normal umbilical cord flow



Absent diastole flow
in umbilical cord



Reversal of diastolic flow
in umbilical cord



S,D and mean indices of Doppler flow

Vessels examined

Umbilical artery (UA)

- Embryo – no end-diastolic flow in the umbilical artery
- Fetus – umbilical artery will demonstrate increasing diastolic flow with advancing gestational age
- Umbilical artery S/D ratio declines with increasing gestational age
- Umbilical artery PI declines with increasing gestational age
- Normal umbilical artery S/D = less than 3.0 at 30+ weeks gestational age

Umbilical vein

- Embryo – umbilical vein demonstrates pulsatile, low velocity flow
- Fetus – umbilical vein flow is non-pulsatile

Fetal middle cerebral artery (MCA)

- Assessment of brain sparing in circulation of Intrauterine Growth Restriction (IUGR) fetuses
- Continuous flow in the brain is normal throughout all stages of the pregnancy
- Normal MCA S/D = 7 or greater at 25 weeks gestational age and decreasing with advancing gestational age
- MCA PI/ UA PI allows for assessment of brain sparing (normal MCA PI/UA PI = greater than 1)

Fetal aorta

- Flow volume and systolic, diastolic and mean velocity increase with increasing gestational age, stabilizing near term
- Fetal aorta S/D ratios decrease with gestational age
- Changes are in response to decreasing placental resistance in later gestation
- Ductus venosus

Fetal inferior vena cava (IVC)

- Triphasic when measured close to the fetal heart
- As Doppler sample is obtained distal to the fetal heart, the waveform becomes more biphasic
- Heart rate and fetal breathing movement influence waveform

Renal arteries

- Fetal renal artery Doppler is a technically difficult exam producing a lower predictive value for IUGR
- Color Doppler can be helpful to determine renal agenesis and other fetal renal anomalies
- Normal renal artery PI decreases linearly from 18 to 42 weeks
- Renal artery RI increases in asymmetric growth retardation

Placenta

- Color/power Doppler assists in characterization of placental cysts, chorioangiomas, and areas of abruption
- Color/power Doppler enhances diagnosis of accreta and characterization of penetration of placental vessels into the myometrium

Maternal uterine artery

- Easiest obtained during vaginal scanning
- Small but significant decrease in Doppler indices with increasing gestational age
- Important barometer or baseline to distinguish fetal conditions from maternal conditions as a source of complication
- Presence of diastolic notch after 24 wks gestation could indicate an adverse outcome relative to abnormal downstream resistance associated with IUGR or preeclampsia, for example

Pearls and pitfalls

- UA – fetal breathing affects ratios – as fetal HR increases there is an associated decrease in pulsatility of the UA
- Ratios are higher if measured at the fetal end of the cord rather than the placental end
- Fetal breathing affects umbilical vein pulsatility
- Ominous Doppler features
 - Reversed end-diastolic flow in the following:
 - Fetal aorta
 - Umbilical artery
 - Ductus venosus
 - Pulsatile umbilical vein (other than during fetal breathing)

Clinical sources

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Ultrasound, Bothell, WA

Janet Boyd-Kristensen, RDMS, RVT,
Snohomish, WA.

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Gynecology



Guide to vaginal sonography of the nongravid female pelvis

Indications

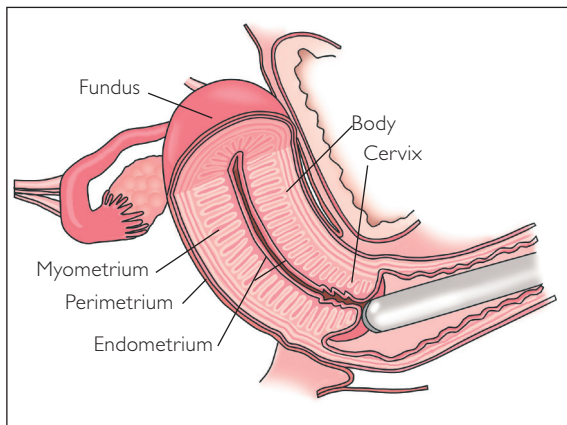
- Abnormal bleeding
- Assisted reproductive monitoring
- Pelvic pain
- Large ovaries or uterus during manual exam
- Follow up on known pelvic masses
- Location of an intrauterine contraceptive device (IUD)

Anatomy

Uterine

The centrally located uterus has three divisions: the body, fundus and the cervix.

- **Fundus** – the portion of the uterus that is superior to the corona of the uterus.
- **Body** – the pear shaped upper 2/3 of the uterus that is the largest organ in the pelvis.
- **Cervix** – inferior 2.5 cm portion of the uterus that protrudes into the distal vagina. Measured from internal os to external os.



The round and broad ligaments are part of the support system that holds the anteverted and anteflexed uterus within the pelvis. The levator ani muscles and pelvic fascia, located in the pelvic floor, support the uterus.

The uterine wall itself has divisions that become important when establishing the location of fibroids.

- **Endometrium** – inner layer of the uterus that has a thin, smooth mucous lining.
- **Myometrium** – smooth muscle running longitudinal and circular composing the largest portion of the uterus.
- **Perimetrium** – a layer consisting of connective tissue that is part of the peritoneum, often referred to as the serous coat or layer.

Ovarian

The paired ellipsoid-shaped ovaries are located in the ovarian fossa. The fossa boundaries include the superior and laterally located internal iliac artery and vein, and the lateral pelvic wall. The superior surface of the ovary provides the location of attachment for the fallopian fimbria and the ovarian suspensory ligament.

The two layers of the ovary, the medulla and cortex, have different functions for the mature woman. During the menstrual cycle, the cortex produces the follicles that result in ovulation. The medulla, located centrally, contains the connective tissue, blood, lymphatic vessels and smooth muscle of the ovary.

Fallopian tube

The muscular fallopian tube begins at the cornua of the uterus and ends with fimbriae in the area of the ovary. This 7-12 cm (3-5 in) tubular structure has four divisions along the length.

- **Cornua** – one-centimeter long section of the tube that passes through the uterine wall just below the fundal area.
- **Isthmus** – the mid portion of the fallopian tube.
- **Ampulla** – the largest portion of the fallopian tube that is able to dilate with pathology or an ectopic pregnancy. This thin-walled section curves over the ovary.
- **Infundibulum** – this lateral portion has many fingerlike projections (fimbriae), one of which, the fimbriae ovarica, connects to the ovary.

The fallopian tube also has three layers, from outer to inner, which include the outer serosal, mid-muscular, and the internal mucous layers.

Endometrium

Two layers compose the endometrium.

- **Zona functionalis** – this functional layer is the superficial portion composed of glands and stroma.
- The uterus sheds this layer at the end of the menstrual cycle.
- **Zona basalis** – the thin layer that regenerates the endometrium after menstruation.

Vascular

The L-5/S-1 vertebral junction marks the bifurcation level of the internal and external iliac vessels. The internal iliac artery supplies most of the pelvic organs with branches of the anterior internal iliac artery. One branch, the uterine artery, courses medially to the cervix where it changes direction and ascends lateral to the uterus. At the cornua, the uterine artery again changes direction traveling laterally to the hilum of the ovary where it terminates at the anastomosis with the ovarian artery. The venous flow parallels the arterial supply.

The ovarian arteries originate inferior to the renal arteries on the lateral side of the aorta. Within the pelvis, the artery crosses the external iliac artery and begins traveling medially within the suspensory ligament of the ovary. The uterine and ovarian artery provides a dual blood supply to the ovary.

Measurements

Uterine

The uterus varies in size due to age and parity. Length measurements extend from the fundus to the cervix, on transverse the entire width, and the anteroposterior (AP) a maximum height on a perpendicular plane. Measuring the uterus on an oblique AP plane overestimates the height.

Ovarian

Ovarian volume helps determine normalcy since many factors change the measured size. These include the point in the endometrial cycle during scanning, age and body habitus. A normal ovary has a rough measurement of 3 x 2 x 2 cm (volume 6.27 ml) with an almond shape.

Life cycle	Volume (cm3)
Prepubertal	3.0
Postpubertal	4.0
Reproductive	9.8
Postmenopausal	5.8

Derived from tables and text located in references 1, 2 and 3.

Volume measurements derived from the formula $0.523 (L \times W \times H)$

(L X W X H)

	Length (cm)	Width (cm)	AP (cm)	Volume (ml)
Prepubertal	3.0	0.5-1.5	1.0	0.8-2.4
Postpubertal	6-7	2.0-2.5	2.0-2.5	14.69-22.88
Adult				
Nulliparous	6.0-8.0	3.0-5.0	3.0-5.0	12.5-104.6
Multiparous	8.0-11.0	5.0-6.0	5.0-6.0	104.6-207.1
Menopausal	3.0-5.0	2.0-3.0	2.0-3.0	6.27-23.53

Derived from tables located in references 1, 2 and 3.

Volume measurements derived from the formula $0.523 (L \times W \times H)$

Endometrium – fertility

The endometrium contains two layers, the anterior and posterior portion. Measurement of both layers on the sagittal plane determines the thickness. This “double layer” measurement does not include the hypoechoic halo that is the zona basalis.

Endometrial phase	Thickness (Multilayer, mm)	Day in cycle
Menstrual phase	2-4	1-4
Proliferative (follicular) phase	4-8	5-10
Periovulatory period	6-10	11-17
Secretory (luteal) phase	7-14	18-28

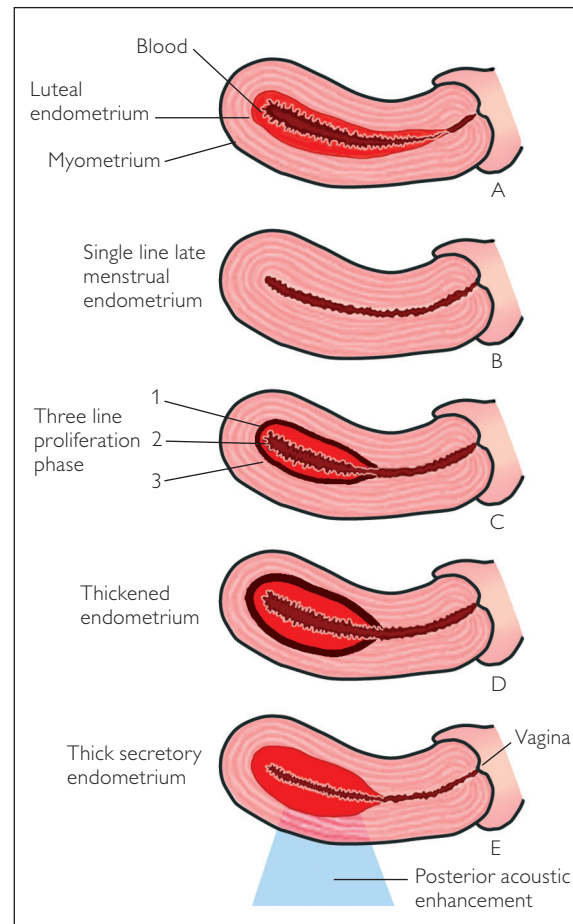
Derived from text located in references 1, 2 and 7.

Endometrium – postmenopausal

The postmenopausal endometrium images on the sonogram as a thin echogenic line within the uterus. Patient symptoms and hormone status change the normal range for the perpendicular AP measurement of the endometrium. Other sonographic parameters to identify are homogeneity and contour regularity.

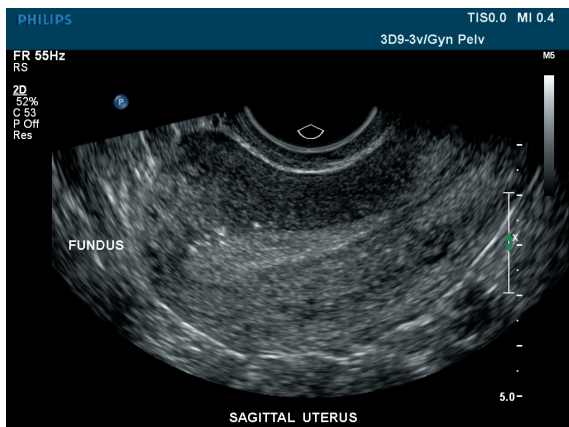
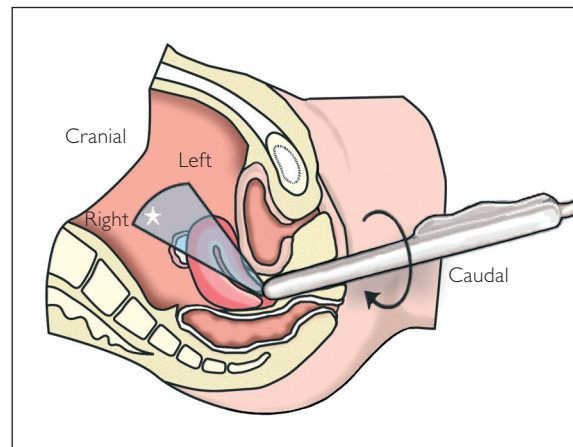
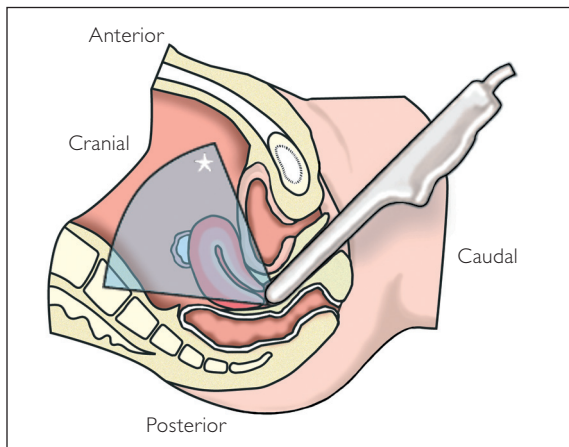
Postmenopausal status	Thickness (double layer, mm)
No symptoms	less than 8
Bleeding	≥ 5
HRT	≤ 8
Tamoxifen	≥ 6

Derived from references 1 and 2.

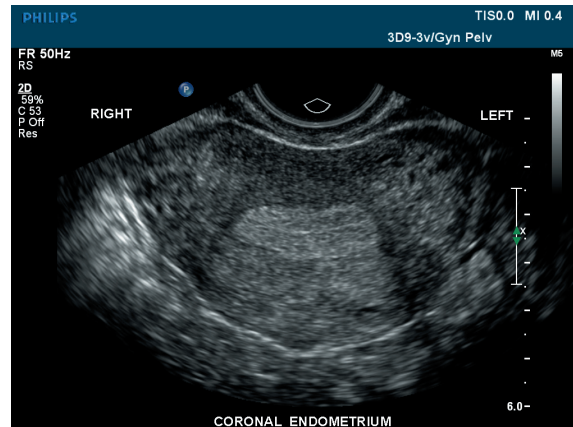


The uterine lining changes throughout the normal menstrual cycle. The proliferative phase (C) images with a triple echo pattern and is an indication for timing of fertilization.

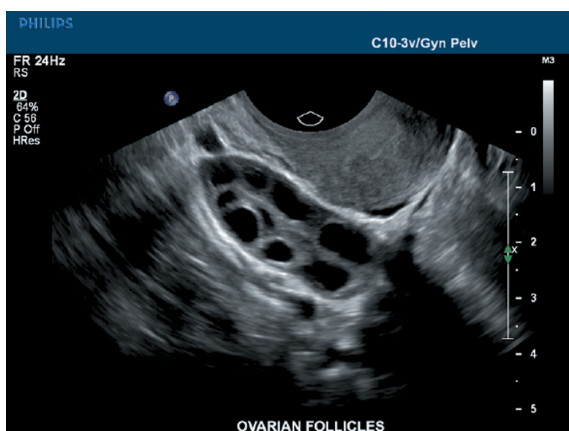
Scanning planes and orientation



The sagittal scanning plane orientation displays the superior/fundal portion of the uterus on the left side of the screen.



The coronal plane orientates with the right side of the body on the left side of the screen.



Scanning tips

- Reduce sector size to increase detail and frame rate.
- Steer beam to reduce patient discomfort.
- To help visualize an ovary and/or uterus:
 - Roll patient away as appropriate
 - Push organ into the field of view with external palpation
- Have patient empty urinary bladder.
- Reverse Trendelenberg exam table or have patient raise torso and prop on elbows.
- Have patient take a deep breath and observe movement of pelvic organs.
- Elevate patient's hips with support wedge

Clinical source

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RDMS, RVT, RT(R)(CT)
Philips Ultrasound, Bothell, WA

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Guide to gynecologic Doppler sonography

Indications

- Assessment of pelvic pain to rule out:
 - Abnormal ovarian, uterine and endometrial flow
 - Pelvic congestion syndrome
 - Postpartum ovarian vein thrombus (PPOVT)
 - Ovarian torsion
- Determination of abnormal vaginal bleeding
- Abnormal beta hCG
 - Ectopic, retained products of conception or hydatidiform mole
- Enlarged uterus and ovary
- Location of uterine artery for embolization to treat leiomyomas
 - Peripheral leiomyoma flow
 - Evaluation of corpus luteum
 - Increased neovascularity/ovarian stroma for suspected masses
 - Evaluation of papillary excretions, septations and solid masses in ovary

Anatomy

- Main uterine artery is a branch from internal iliac artery. It courses to the cervico-corporal junction of the uterus and bifurcates into the ascending and descending branches
- Arcuate arteries branch from the uterine artery and terminate in the radial arteries located in the myometrium. Smaller spiral arteries supply blood to the endometrium
- Main ovarian artery is a branch from aorta and courses along the infundibulopelvic ligament

- Ovarian vascular supply
 - Arterial
 - One from the main ovarian artery
 - One from the adnexal branch of the uterine artery
 - Venous
 - Pampiniform plexus within the pelvis fuses to create the ovarian vein
 - Right ovarian vein drains into the IVC while the left drains into the left renal vein
- There are 5-10 arterial branches which penetrate the ovarian capsule
 - The intraovarian arteries are coiled except in area of the corpus luteum where there is a vascular ring with low impedance flow
 - Venous supply generally parallels the arterial supply.

Technique

Sample volume placements

- At the adnexal branch of the ovarian artery imaged at the uterine corpus
- At the ovarian periphery and internal stroma

Waveform

- Obtain 3 or more values
- Obtain RI or PI
 - $RI = \frac{\text{Systolic} - \text{Diastolic}}{\text{Systolic}}$
 - $PI = \frac{\text{Systolic} - \text{Diastolic}}{\text{Mean}}$
- Sample ovary, uterus, abnormal areas such as papillary projections, wall thickenings or cystic/solid structures
- Sample contralateral ovary for comparison

Measurements/interpretation

Uterus – normal flow in non-gravid uterus has high-impedance pattern

- Low impedance flow due to arteriovenous malformations
- Increased vascularity in periphery of fibroids

Ovary – menstrual and follicular stages exhibit high-impedance flow

- Increased diastolic flow in the luteal phase
- Low impedance flow in corpora lutea or inflammatory masses
- Normal ovarian artery demonstrates early diastolic notch

Doppler findings

Ovarian torsion

- Findings vary according to the degree and duration of the torsion
- Associated with an ovarian mass
- An early torsion finding is a lack of intraovarian venous flow
- Ovarian arterial blood supply may still be present if there is partial torsion of the vascular pedicle or if one of the two arteries that supply the ovary is patent
- High impedance arterial flow is seen in the adnexal branch of the uterine artery in complete ovarian torsion
- Ovarian torsion may retain notch of normal waveform

Polycystic ovarian syndrome (PCOS)

- Increased stromal arterial blood flow
- Decreased ovarian artery RI/PI flow
- Increased uterine artery RI/PI flow

Pelvic congestion syndrome

- Varicose veins in the pelvis due to blood pooling affecting the uterine and ovarian veins
- Sonographic signs include engorged pelvic veins that exhibit increased color flow with a Valsalva maneuver or with the patient in an erect position

Postpartum ovarian vein thrombus (PPOVT)

- Produces large veins in pelvis
- Right thrombus more common than left
- Monitoring of veins after anticoagulant therapy

Ectopic

- Low-impedance flow at implantation site
- Separate ectopic color flow from ovarian signal. The adnexal flow images as a ring of flow separate from the ovary
- Monitor methotrexate treatment with reduction of flow in ectopic
- Differentiate between ectopic and pseudogestational sac with color flow imaging

Hydatidiform mole

- Hypervascular flow within the myometrium may indicate trophoblastic disease
- High peak systolic and diastolic flow within the uterine artery due to decreased vascular impedance
- Decreased RI/PI due to increased diastolic flow

Pearls and pitfalls

- Set system to detect slow velocities by lowering the scale (PRF)
- Scan contralateral side to establish normal baseline
- Venous imaging aided by the performance of a Valsalva maneuver

Clinical sources

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Donna Kepple, RDMS, FAIUM, Consultant

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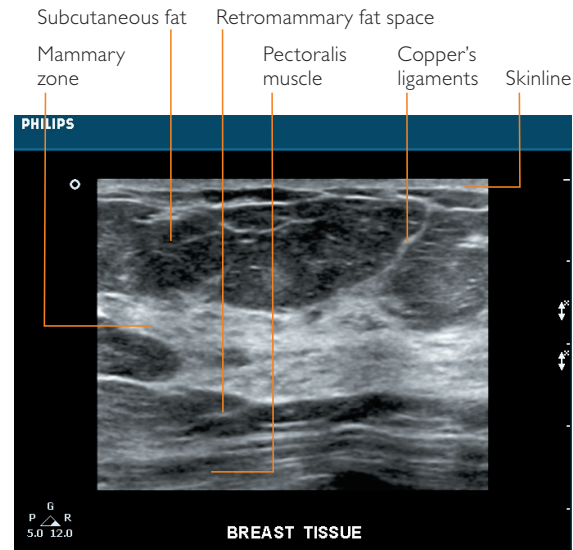
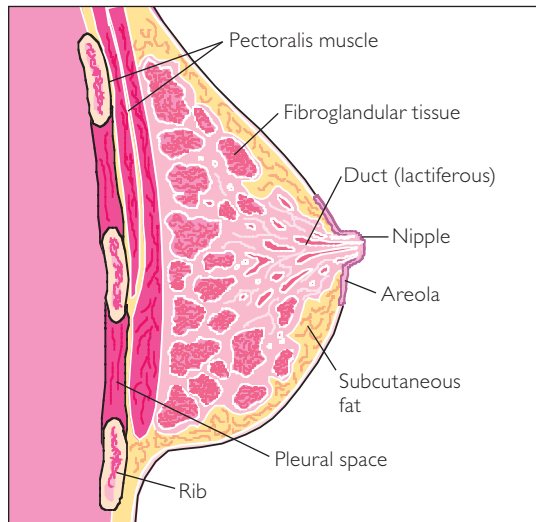
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Breast



Guide to sonography of the breast



This image demonstrates most of the anatomical elements encountered by breast sonography.

Ultrasound of the breast has been performed for more than a decade, with exam protocol continuously evolving based on image quality of the current equipment. Sonography provides a noninvasive, tomographic display of the breast without ionizing radiation. Continuing advances in digital technology bring added benefits to ultrasound as a useful complement to mammography and physical examination in the evaluation of breast disease. The adjunctive use of high-frequency imaging ultrasound with mammography provides increased confidence in differentiating solid lesions to determine those that are benign, reducing the need to biopsy many lesions considered indeterminate on mammograms.

Breast anatomy

Sonography of the breast requires that the sonologist or sonographer has a comprehensive knowledge of the anatomy of the breast. The sonographic presentation of the breast, which is composed of fat, fibrous tissue and glandular tissue, depends greatly on the hormonal status of the patient.

Sonographic anatomy of the breast

- Skin
- Retromammary fat
- Subcutaneous fat
- Pectoralis muscle
- Breast parenchyma (mammary zone)
- Ribs/pleura
- Nipple region
- Copper's ligaments
- Tail of Spence

The skin is seen as a highly reflective band along the surface of the breast. Normal thickness is 2 mm. Subcutaneous fat lies between the skin and the parenchymal (mammary zone) tissue. The quantity of fat varies. Fibroglandular tissue is the echogenic layer of tissue beneath the nipple and subcutaneous fat. Once again the ratio of fat versus fibroglandular tissue varies among patients and may also depend on the age, parity and hormonal status of the patient.

Cooper's ligaments are suspensory ligaments, providing support to the glandular structures of the breast. They extend radially from the deep fascial planes to the skin. Retromammary fat forms a layer between the deep fascial plane of the breast and the pectoral muscle, defining the posterior boundary of the glandular tissue. The pectoralis muscles can be clearly imaged sonographically in the direction of their fibers. They appear above the ribs and parallel to the skin. The clinician must have a clear understanding of normal appearance to evaluate the area for tumor extension.

The ribs are readily identified laterally because bone attenuates the sound beam, resulting in acoustic shadowing. Medically, the ribs appear as hypoechoic structures containing low-level echoes.

The nipple region requires special attention because it consists of both dense connective tissue (of the nipple) and partially connective tissue of the lactiferous ducts, which can cause posterior acoustic shadowing.

The tail of Spence (axillary tail) is the portion of the breast that extends into the axillary region.

Technique

The examination of the breast with ultrasound requires a preview of the mammogram as well as a good physical examination and patient history.

The patient history should include:

- Family history
- Age
- Previous mammograms
- Parity
- Masses
- Gravida
- Scars
- Aborta
- Skin changes
- Medications (hormones)
- Nipple discharge
- Surgeries of the breast
- Breast contour

Upon completing a thorough review of the patient's history, mammograms, and physical examination, the breast ultrasound exam can begin. The patient is scanned supine with the ipsilateral hand either above the head

or on the hip with the elbow pointed back. This causes the breast to flatten across the pectoralis muscle. Depending on the size of the breast, multiple scanning positions may be required. A cushion is placed behind the shoulder of the breast being examined. These techniques help stabilize the breast and provide reproducible positioning if open surgery is required.

The breast is then scanned with a high-frequency (at least 7-15 MHz) transducer. The breast may be scanned longitudinally or transversely. Stavros et al. recently described scanning of the breast in the radial and antiradial presentation. Regardless of which method is used, the breast needs to be examined in two or more orthogonal imaging planes when a mass is identified.

The breast also needs to be clearly labeled while scanning is being performed. While the “face of the clock” is the most common labeling method, others prefer to divide the breast into four quadrants. Regardless of the method used, consistency must be maintained to allow reproducibility in follow-up scans and quality control within imaging.

It is important to pay close attention to the nipple area when scanning, since a shadow can be caused by the erection of the nipple. In this case, either apply more pressure, use more gel, or scan the nipple area obliquely. Scanning the nipple region obliquely is easily performed by placing a rolled-up towel between the patient's breasts. By having her roll onto her side, the nipple of interest will be on top. The nipple can then be scanned from the side. This reduces the shadowing, avoids the need for a standoff pad, and provides adequate visualization of the anatomy posterior to the nipple.

Indications for breast ultrasound

Breast ultrasound is used as an adjunct to mammography and physical examination. The most common indications to perform an ultrasound exam are the presence of a palpable mass or discovery of a mass on mammogram. Ultrasound assists in identifying the mass as cystic or solid. High-frequency imaging assists in differentiating solid masses and identifying those lesions that are more likely benign and for whom a tissue diagnosis biopsy is more optional. This information enables the physician and patient to make a decision as to how to manage the mass.



Ultrasound guidance of aspiration, fine needle aspiration (FNA) and core biopsies is a rapidly growing application for ultrasound of the breast. With advances in technology, ultrasound-guided needle biopsies offer both the patient and the sonologist a simple, effective choice in breast management.

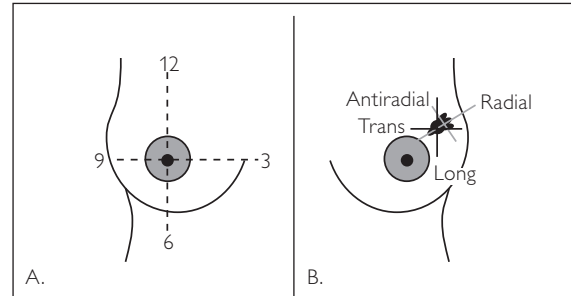
Indications

- After abnormal mammogram for differentiation between cysts and solid masses
- For differentiation of solid masses to determine more likely benign lesions
- Palpable mass not visible in a radiographically dense breast
- Young, pregnant or lactating patient with a palpable mass
- Suspected abscess in infected breast
- Mass that cannot be completely evaluated with mammography because of location
- Guidance for interventional procedures

Other potential circumstances for ultrasound examination include suspected leaks from silicone implants and oncology follow-up.

Sonography is advantageous because it provides a painless, noninvasive tomographic study of the breast. The strengths of sonography complement mammography, providing additional anatomical information and increasing diagnostic confidence.

The evaluation of masses in the breast has been traditionally one of investigating cystic versus solid. Using high-frequency ultrasound, even more information is obtainable and solid masses can be evaluated based on their ultrasound characteristics. The ability to differentiate benign masses from other suspicious tissue may reduce the need for biopsy for many patients.



The breast can be scanned longitudinally or transversely whether the entire breast is scanned or just an area of interest (see Figure A). If a mass is discovered, the radial/antiradial approach can help further identify borders and the possibility of ductal extension (see Figure B).

Ultrasound characteristics

- Margins
- Shape
- Echogenicity
- Echotexture
- Orientation
- Posterior acoustic attenuation pattern

Overview of differentiating solid breast masses with high-frequency ultrasound

Extensive use of ultrasound for adjunctive breast exams has shown that lesions have definite image characteristics that indicate benign appearance. When a solid breast mass is encountered, the following criteria should be evaluated:

- Margins: degree of irregularity
 - Benign masses usually are indicated by smooth margins.
 - Malignant tumors appear aggressive and may have finger-like extensions or spiculations.
- Shape: ovoid, irregular, lobulated or spherical
 - Benign masses usually are spherical or ovoid – a smooth, round or egg shape. Stavros has found that lesions with three or less gentle lobulations are usually benign.
 - Malignant masses tend to be variable or irregular in shape.

- Echogenicity and echotexture: characterization of echo pattern and texture
 - Benign masses usually are homogeneous, or of equal or lower echogenicity to the surrounding tissue, and have uniform internal echoes.
 - Malignancies are most often heterogeneous with a variety of echotextures, predominately hypoechoic.
- Orientation: position to tissue planes
 - Benign lesions usually grow parallel to tissue planes.
 - Malignant masses tend to invade surrounding tissue and cross tissue planes.
- Posterior acoustic attenuation pattern: degree of sound beam absorption
 - Benign solid masses have minimal through transmission and cystic lesions have high transmission of sound.
 - Malignant masses may absorb the sound beams and cause echoes posterior to their location to be very black and chaotic. Shadowing is also chaotic or random. (Colloid cancers may have through transmission.)

Simple cysts

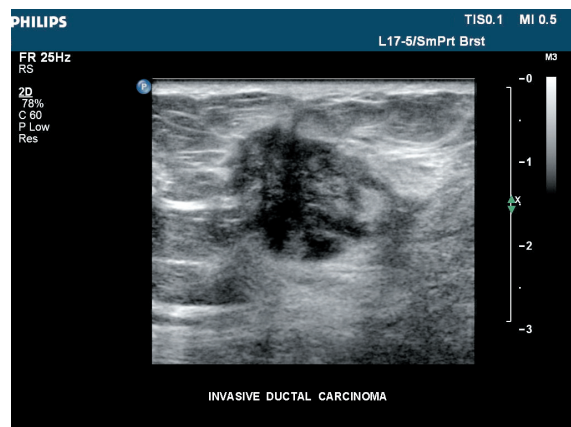
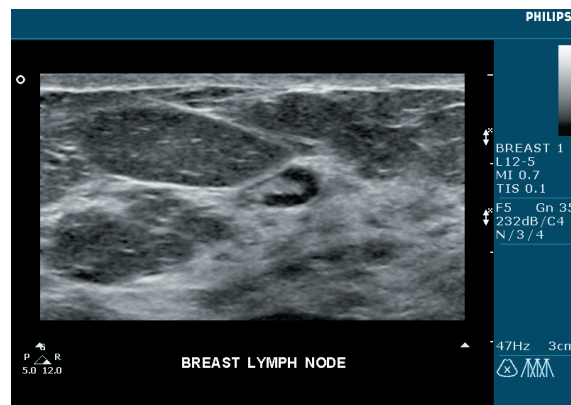
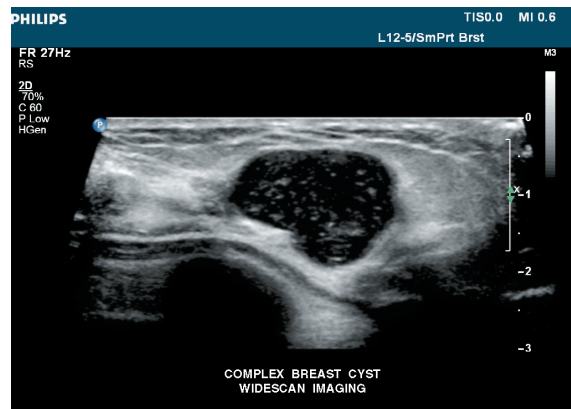
- Completely anechoic
- Well-circumscribed
- Thinly-encapsulated
- Enhanced through transmission
- Thinly-edged shadows

Solid masses – probably benign

- Oval shape
- Smooth defined borders
- Uniformly low or medium-level internal echoes
- Minimal attenuation, if any
- Wider than tall
- Two to three gentle lobulations

Malignant masses

- Variable shapes
- Irregular, ill-defined borders
- Low-level, non-uniform internal echoes
- Taller than wide
- Posterior attenuation



Clinical source

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