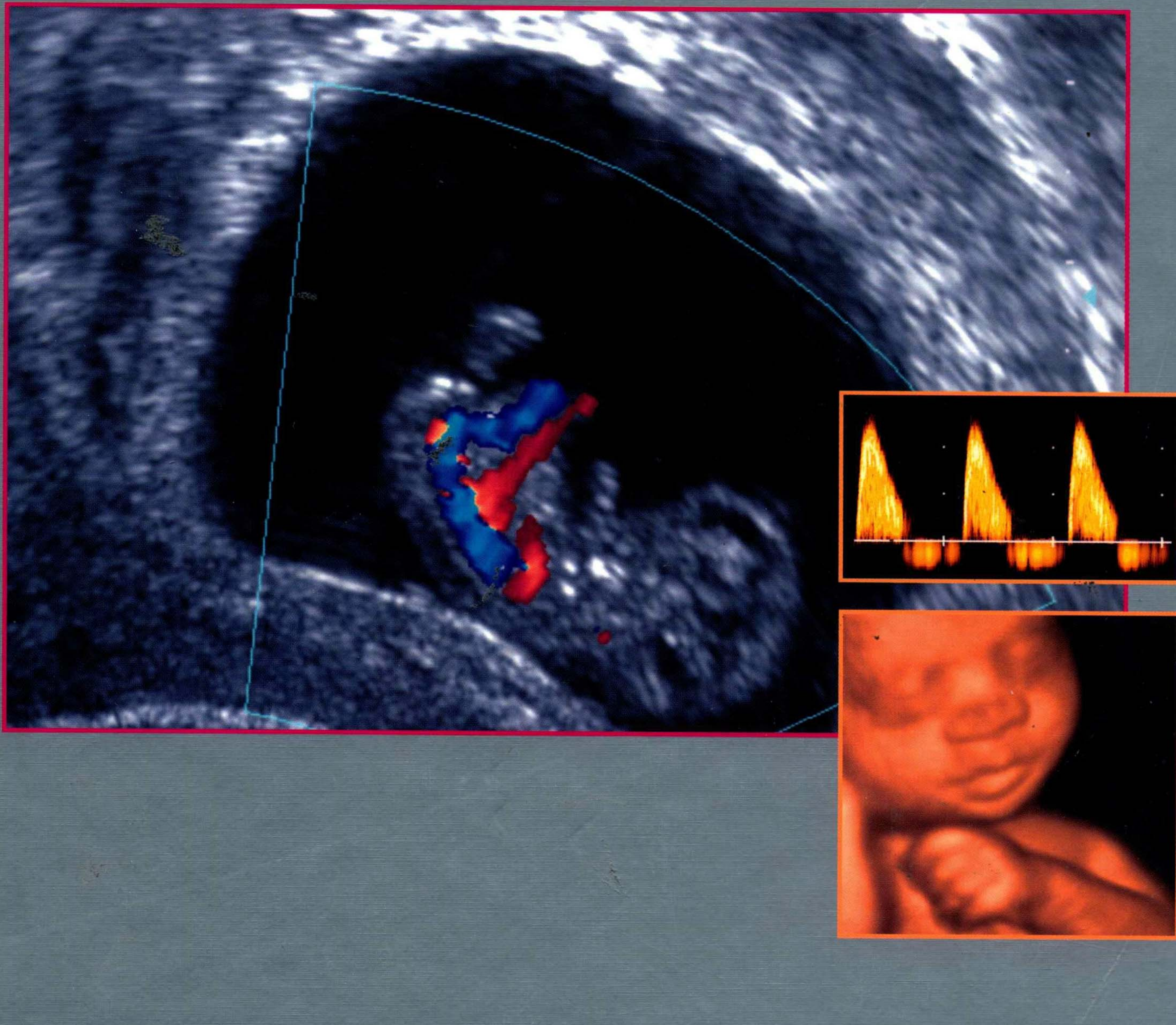
# Ultrasound in Obstetrics and Gynecology

## Vol. 1: Obstetrics

Eberhard Merz

Second edition, fully revised



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# Ultrasound in Obstetrics and Gynecology

## Volume 1: Obstetrics

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Humanity owes its progress to the dissatisfied.

— *Aldous Huxley*

For Christine, Beatrice and Véronique

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# Preface to the Second Edition

When I. Donald, J. MacVicar, and T. G. Brown published the first obstetric ultrasound images in *Lancet* in 1958, they could not have envisioned the tremendous advances and extensive use that diagnostic ultrasound would achieve in prenatal diagnosis during subsequent decades. The basic evolution of diagnostic ultrasound has been from A-mode to B-mode scanning, then to real-time 2-D imaging and color Doppler sonography, and finally to real-time 3-D ultrasound technology. This progress has included many smaller but no less important evolutionary steps, such as advances in transducer designs and innovations in computer hardware and software. Today we have at our disposal a sophisticated sonographic technology that not only provides an increasingly detailed look at embryonic and fetal development and physiology but also permits the early detection of numerous pathologic conditions. As a result, the ultrasound examination has become an indispensable part of prenatal diagnosis and treatment.

Given the broad range of developments in ultrasound technology, it is not surprising that the number of publications dealing with ultrasonography have reached startling proportions. This has made it difficult even for specialists in obstetric ultrasound to keep abreast of the latest developments.

This second edition of *Ultrasound in Gynecology and Obstetrics* is designed to provide the prenatal diagnostician with a comprehensive, up-to-date review of transvaginal and abdominal sonography as they are applied to obstetrics. Besides offering copious information and illustrations, each chapter concludes with an extensive list of bibliographic references. As in the gynecologic volume, sonographic images in this volume are matched with clinical photographs so that the observer can gain a clearer appreciation of pathologic findings. This edition also gives special attention to biometry, providing growth charts and an appendix with tables listing the normal values that are most relevant to prenatal diagnosis.

The combined efforts of 26 contributors have resulted in a textbook and atlas that will familiarize hospital and office practitioners with the current applications of the various ultrasound techniques used in prenatal diagnosis and treatment while also guiding physicians in the sound and discriminating clinical use of these techniques.

I express thanks to all of my coauthors, who have contributed decisively to the success of this book. I also thank Dr. J. Bohl (Dept. of Neuropathology, University of Mainz) for preparing the pathoanatomic brain sections, Prof. H. Müntefering (head of the Dept. of Pediatric Pathology, University of Mainz) for providing various images of pathologic conditions, Prof. J. W. Spranger (executive director of the Mainz University Pediatric Hospital) for his help in reviewing the nomenclature for fetal limb anomalies, and Prof. S. Wellek (director of Mannheim Central Institute, Dept. of Biostatistics) for his extensive help in constructing growth charts and tables.

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Finally, I am honored to thank Mr. Albrecht Hauff, the president of Thieme Medical Publishers, for the splendid production work that has gone into this book. I am also indebted to the staff at Thieme. Dr. Markus Becker (program planning), Dr. Antje Schönpflug (editorial), and Mr. Rolf-Dieter Zeller (production) worked with great understanding of my concepts and wishes in bringing this second edition to a successful completion.

Mainz, Summer, 2004 *E. Merz*

# Abbreviations

| | |
|---|---|
| **AAPSS** | = American Academy of Pediatrics Surgical Survey |
| **ABCD** | = airway, breathing, circulation, differential diagnosis |
| **AC** | = abdominal circumference |
| **AChE** | = acetylcholinesterase |
| **ACOG** | = American College of Obstetricians and Gynecologists |
| **ADAM** | = amniotic deformity, adhesions, mutilations |
| **ADPKD** | = autosomal-dominant polycystic kidney disease |
| **AEDF** | = absent end-diastolic flow |
| **AFI** | = amniotic fluid index |
| **AFP** | = alpha-fetoprotein |
| **AGS** | = adrenogenital syndrome |
| **AMC** | = arthrogryposis multiplex congenita |
| **ANF** | = atrial natriuretic factor |
| **Ao** | = Aorta |
| **AP** | = anteroposterior |
| **ARPKD** | = autosomal-recessive polycystic kidney disease |
| **ASD** | = abdominal sagittal diameter; atrial septal defect |
| **AT** | = acceleration time |
| **ATD** | = abdominal transverse diameter |
| **AV** | = atrioventricular |
| **AVP** | = arginine vasopressin |
| **AVSD** | = atrioventricular septal defect |
| **BPD** | = biparietal diameter |
| **BTC** | = bony thoracic circumference |
| **BTSD** | = bony thoracic sagittal diameter |
| **BTTD** | = bony thoracic transverse diameter |
| **BV** | = bladder volume |
| **CATCH 22** | = cardiac defects, abnormal facies, thymic hypoplasia, cleft palate, hypocalcemia (caused by defects in chromosome 22) |
| **CAVSD** | = complete atrioventricular septal defect |
| **CCAM** | = congenital cystic adenomatoid malformation |
| **CCHB** | = complete congenital heart block |
| **CHAOS** | = congenital high airway obstruction syndrome |
| **CMV** | = cytomegalovirus |
| **CNS** | = central nervous system |
| **COFS** | = cerebro-oculofacioskeletal syndrome |
| **CPM** | = confined placental mosaicism |
| **CRL** | = crown-rump length |
| **CRP** | = C-reactive protein |
| **CSF** | = cerebrospinal fluid |
| **CT** | = computed tomography |
| **CT ratio** | = ratio of cardiac and thoracic diameters |
| **CTA ratio** | = ratio of cardiac and thoracic areas |
| **CTG** | = cardiotocography, cardiotocogram |
| **CVS** | = chorionic villus sampling |
| **CW** | = continuous wave |
| **DA** | = ductus arteriosus |
| **DEGUM** | = Deutsche Gesellschaft für Ultraschall in der Medizin (German Society for Ultrasound in Medicine) |
| **DOLV** | = double-outlet left ventricle |
| **DORV** | = double-outlet right ventricle |
| **D-TGA** | = dextro-transposition of the great arteries |
| **ECG** | = electrocardiography, electrocardiogram |
| **ECHO** | = enteric cytopathic human orphan |
| **EUROCAT** | = European Union Registry of Congenital Anomalies and Twins |
| **FHR** | = fetal heart rate |
| **FHRP** | = fetal heart rate pattern |
| **FL** | = femur length |
| **FISH** | = fluorescence in-situ hybridization |
| **FI** | = fibula |
| **FTA-ABS** | = fluorescence treponemal antibody absorption (test) |
| **GEPH** | = gestational edema, proteinuria, and hypertension |
| **GIFT** | = gamete intrafallopian transfer |
| **HC** | = head circumference |
| **hCG** | = human chorionic gonadotropin |
| **β-hCG** | = β-human chorionic gonadotropin |
| **Hct** | = hematocrit |
| **HELLP** | = hemolysis, elevated liver enzymes, and low platelet count (syndrome) |
| **HIV** | = human immunodeficiency virus |
| **HLA** | = human leukocyte antigen |
| **HLHS** | = hypoplastic left heart syndrome |
| **HSV** | = herpes simplex virus |
| **ICSI** | = intracytoplasmic sperm injection |
| **ICU** | = intensive-care unit |
| **IFMSS** | = International Fetal Medicine and Surgery Society |
| **IPIR** | = intercostal-to-phrenic inhibitory reflex |
| **IPKD** | = infantile polycystic kidney disease |
| $I_{spta}$ | = spatial peak temporal average intensity |
| **IUD** | = intrauterine device |
| **IUFD** | = intrauterine fetal death |
| **IUGR** | = intrauterine growth retardation |
| **i.v.** | = intravenous |
| **IVC** | = inferior vena cava |
| **IVF** | = in-vitro fertilization |
| **IVF/ET** | = in-vitro fertilization/embryo transfer |
| **IVS** | = interventricular septum |
| **LCM** | = lymphocytic choriomeningitis |
| **LD** | = lung diameter |
| **LD/BTC** | = ratio of lung diameter and bony thoracic circumference |
| **LGA** | = large for gestational age |
| **LSVC** | = left superior vena cava |
| **L-TGA** | = levo-transposition of the great arteries |
| **LV** | = left ventricle |
| **MCV** | = mean corpuscular volume |
| **MI** | = mechanical index |
| **MIS** | = minimally invasive surgery |
| **MRI** | = magnetic resonance imaging |
| **MSAFP** | = maternal serum alpha-fetoprotein |
| **MTX** | = methotrexate |
| **Nd:YAG** | = neodymium-yttrium aluminum garnet |
| **NIHF** | = nonimmune hydrops fetalis |
| **NSE** | = neuron-specific enolase |

NT = nuchal translucency
ODS = Online Display Standard
OEIS = omphalocele, exstrophy, imperforate anus, spinal defects
OFD = occipitofrontal diameter
PA = pulmonary atresia
PA/IVS = pulmonary atresia with an intact ventricular septum
PAPP-A = pregnancy-associated plasma protein-A
PAPVR = partial anomalous pulmonary venous return
PCD = power color Doppler
PCR = polymerase chain reaction
$PGE_2$ = prostaglandin $E_2$
$PGI_2$ = prostaglandin $I_2$ (prostacyclin)
PI = pulsatility index
PIH = pregnancy-induced hypertension
$PLA_1$ = phospholipase $A_1$
PLSVC = persistent left superior vena cava
PND = prenatal diagnosis
PRF = pulse repetition frequency
PSVT = paroxysmal supraventricular tachycardia
PT = pulmonary trunk
Ra = radius
RA = Right atrium
RADIUS = Routine Antenatal Diagnostic Imaging Ultrasound Study
REM = rapid eye movement
RF = reverse flow
RI = resistance index
ROI = region of interest
RV = right ventricle
SCID = severe combined immunodeficiency
SD = standard deviation
SGA = small for gestational age
SLE = systemic lupus erythematosus
SPTA = spatial peak temporal average
STIC = spatial-temporal image correlation
$T_3$ = triiodothyronine
$T_4$ = thyroxine
TA = tricuspid atresia
TAC = truncus arteriosus communis
TAPVD = total anomalous pulmonary venous drainage
TAPVR = total anomalous pulmonary venous return
TBII = thyrotropin-binding inhibitory immunoglobulin
TC = thoracic circumference
TCD = transverse cerebellar diameter
TDE = tissue Doppler echocardiography
TGA = transposition of the great arteries
Ti = tibia
TI = thermal index
TIB = thermal index for bone
TIC = thermal index for cranium
TIS = thermal index for soft tissues
TOF = tetralogy of Fallot
TORCH = toxoplasmosis, other infections, rubella, cytomegalovirus infections and herpes simplex virus
TP-ELISA = Treponema pallidum enzyme-linked immunosorbent assay
TPHA = Treponema pallidum hemagglutination (test)
TR = trachea
TRAP = twin reversed arterial perfusion
TSD = thoracic sagittal diameter
TSH = thyroid-stimulating hormone
TSI = thyroid-stimulating immunoglobulin
TTD = thoracic transverse diameter
TV = transfusion volume
$TXA_2$ = thromboxane $A_2$
Ul = ulna
V/H ratio = ventricular-hemispheric ratio
VACTERL = vertebral defects, anal atresia, cardiac anomalies, tracheoesophageal fistula with esophageal atresia, renal dysplasia, and limb anomalies
VATER = vertebral defects, imperforate anus, tracheoesophageal fistula, and radial and renal dysplasia
$V_{mean}$ = mean flow velocity
VSD = ventricular septal defect

# Contents

# Ultrasound in Obstetrics

# 1 Ultrasound Applications and Examination Techniques in Obstetrics

Noninvasive and without radiation risk, ultrasound is an ideal imaging modality in pregnancy. Owing to the tremendous evolution of ultrasound technology in recent years, we now have at our disposal a range of sophisticated techniques. The use of a particular technique will depend on the age of the pregnancy and the nature of the investigation. The available options include abdominal and transvaginal 2-D imaging, M-mode studies, Doppler and color Doppler, power color Doppler, and 3-D ultrasound.

## Minimum Equipment Requirements

**Real-time scanner.** Modern ultrasound examinations in pregnancy require at least a real-time scanner with an abdominal transducer operating in the frequency range of 3–5 MHz and calibrated to a sound velocity of 1540 m/s. The transducer should provide an image width of 9.5 cm at a depth of 6 cm, and the system should provide at least 16 levels of gray (International Electrotechnical Commission [IEC] standard 1157). Documentation equipment should consist of a Polaroid or 35-mm camera, a video printer, or a video cassette recorder.

**Vaginal transducer.** A vaginal transducer is recommended for examinations in early pregnancy, although it is not essential. All ultrasound systems currently marketed for use in obstetrics and gynecology come equipped with an endovaginal transducer.

## Transvaginal Ultrasound

### Applications

**First trimester.** Transvaginal ultrasound is used predominantly in the first trimester of pregnancy (1, 4, 8, 9, 14, 15, 16, 18, 20, 22, 24, 26, 28, 30). It can be used at this stage for the early detection of an intact or abnormal intrauterine pregnancy (especially in a retroflexed uterus whose cavity is more distant from the abdominal wall), the early diagnosis of multiple gestation, ectopic pregnancy (7, 23, 29), and fetal anomalies (25). Early transvaginal scanning is also used for the investigation of uterine anomalies (25) and uterine or adnexal masses (Table 1.**1**).

**Late pregnancy.** Transvaginal ultrasound is used much less often in late pregnancy, but it still has selected applications. These include the investigation of deeply situated fetal structures that are not accessible to abdominal scans (e.g., head and brain structures) (2), transvaginal Doppler ultrasound of the uterine artery (11), pelvimetry (10), the evaluation of cervical insufficiency (6, 12, 21, 27), precise evaluation of the internal cervical os to exclude placenta previa (13, 17), and the investigation of uterine bleeding or a mass in the cul-de-sac (Table 1.**1**).

**Advantages.** One advantage of transvaginal ultrasound is that it does not require a full bladder for examinations during early pregnancy. It also provides higher image resolution than abdominal ultrasound, as the structures of interest are always scanned within the focal zone of the transducer (3, 18) (Table 1.**2**). This is particularly advantageous in patients with a retroflexed uterus.

**Disadvantages.** Disadvantages of transvaginal ultrasound are that it displays the pelvic organs from a different perspective than abdominal ultrasound, and it has a limited scanning range in the cephalad direction. This may preclude the use of transvaginal scanning after the uterus has reached a certain size or may limit its use to specialized studies (Table 1.**2**).

Table 1.**1** Applications of transvaginal ultrasound in early and late pregnancy

| **Early pregnancy** |
|---|
| Detection of intact early pregnancy, especially in a retroflexed uterus<br>Early diagnosis of multiple pregnancy<br>Investigation of abnormal early pregnancy<br>Detection or exclusion of ectopic pregnancy<br>Early detection of fetal anomalies<br>Detection of uterine anomalies<br>Investigation of a pelvic mass |
| **Late pregnancy** |
| Fetal structures not accessible to abdominal scan<br>Late detection of fetal anomalies<br>Investigation of oligohydramnios<br>Pelvimetry<br>Diagnosis of cervical insufficiency in the second or third trimester<br>Investigation of placenta previa or low-lying placenta<br>Investigation of uterine bleeding<br>Investigation of a pelvic mass<br>Doppler ultrasound of the uterine artery |

Table 1.**2** Advantages and disadvantages of transvaginal ultrasound in relation to transabdominal ultrasound (adapted from 18)

| **Advantages** |
|---|
| ➢ The examination is performed with an empty bladder, offering several advantages:<br>• Patient can be examined at any time<br>• No waits or delays<br>• Permits optimum comparison with palpable findings<br>• Examination time is not limited by painful bladder distension<br>• Examination can be done in patients who cannot fill their bladder completely |
| ➢ Sharper image resolution than abdominal scans, since the pelvic organs are always within the focal zone of the transducer (especially with a retroflexed uterus) |
| ➢ Image quality not compromised by bowel loops, obesity, or abdominal wall scars |
| ➢ Panoramic scan gives a wide-angle view of the lower pelvis. |
| **Disadvantages** |
| ➢ Unaccustomed viewing angle requires reorientation when imaging pelvic organs. |
| ➢ The mid- and upper abdomen cannot be scanned transvaginally, so the method (aside from special detail studies) is not useful for the routine monitoring of fetal growth and anatomy in the second and third trimesters. |
| ➢ High-sited ovarian tumors are not accessible to transvaginal scans in late pregnancy. |

## Vaginal Transducers

Ultrasound transducers with various frequencies, scanning angles, and fields of view are available for transvaginal use (Fig. 1.**1**). Probes with a larger field of view provide a broader display of the internal genitalia. Most vaginal probes in current use operate at a frequency of 5–7.5 MHz and have a 120° field of view. A mechanical panoramic end-fire transducer offers the largest viewing angle of 240°. While this probe affords a wide-angle survey of the internal genitalia, it does not permit color Doppler imaging, which requires an electronic transducer.

## Transvaginal Examination

**Condom.** Prior to the examination, the vaginal probe is sheathed with a condom that contains some coupling gel. The condom should be of the non-reservoir type, since air bubbles could collect in the reservoir and interfere with imaging. The outside of the condom is wetted with ultrasound gel or NaCl to lubricate the probe and improve acoustic coupling.

**Patient position.** As in gynecology, transvaginal ultrasound in obstetrics can be performed either in a gynecologic examination chair or on an ordinary examination table with the patient supine (Fig. 1.**2**). With the patient's legs flexed and slightly abducted, the probe is carefully inserted into the vagina and advanced just to the cervix.

**Scanning sequence.** The examination starts with a longitudinal midsagittal scan to establish orientation (Fig. 1.**3**). By raising and lowering the probe (Fig. 1.**4**) and angling it from side to side (Fig. 1.**3**), the examiner can explore the entire lower pelvis in various planes of section.

## Image Orientation in Transvaginal Ultrasound

As in gynecology, the transvaginal image in obstetric patients should be displayed such that:

- a transvaginal image is clearly distinguishable from a transabdominal image, and
- a standard orientation system is used for superior/inferior, anterior/posterior, and left/right (5, 19).

The more superior structures should be displayed at the top of the transvaginal image in both sagittal and coronal scans (Table 1.**3**, Figs. 1.**5**, 1.**6**). In longitudinal scans, posterior structures should appear on the left side of the image and anterior structures on the right side (Table 1.**3**, Fig. 1.**5**).

Coronal scans should be anatomically oriented—i.e., structures on the anatomical right side of the lower pelvis should appear on the left side of the image, and structures on the left side should appear on the right (Table 1.**3**, Fig. 1.**6**).

Table 1.**3** Image orientation in transvaginal ultrasound

| **Transvaginal sagittal scan** | |
|---|---|
| Top of image | = superior (cranial) |
| Bottom of image | = inferior (caudal) |
| Right side of image | = anterior (ventral) |
| Left side of image | = posterior (dorsal) |
| **Transvaginal coronal scan** | |
| Top of image | = superior (cranial) |
| Bottom of image | = inferior (caudal) |
| Right side of image | = left |
| Left side of image | = right |

# Abdominal Ultrasound

## Abdominal Examination

**Full bladder.** For abdominal ultrasound in early pregnancy, the maternal bladder should be well distended to displace bowel loops out of the lower pelvis and create an acoustic window for scanning the uterus and conceptus. By the end of the first trimester, the enlarging uterus has displaced the bowel so far cephalad that scanning can be performed with a full or empty bladder.

Abdominal ultrasound is performed routinely at the start of the second trimester. Vaginal ultrasound would be used in exceptional cases such as oligohydramnios, which can compromise abdominal scans, and for visualizing low fetal structures that are not accessible to transabdominal imaging (2).

**Patient position.** Normally the patient is positioned supine (Fig. 1.**7**). The lateral decubitus position may be preferable in late pregnancy to avoid a vena cava occlusion syndrome.

**Scanning sequence.** A routine abdominal examination starts with a longitudinal scan at the center of the lower abdomen (Fig. 1.**8**). This is followed by additional longitudinal, transverse (Fig. 1.**9**) and oblique scans (Figs. 1.**10**, 1.**11**) to obtain detailed views of the fetus (see Chapter 2 for further information).

## Abdominal Transducers

Linear-array, curved-array or sector transducers can be used in obstetric abdominal ultrasound (Fig. 1.**12**). Less experienced examiners should use linear- or curved-array transducers. They are easier to manipulate, and it is easier to locate the desired scan plane than with a sector probe. At the same time, a sector probe require less manipulation to change from one scan plane to another, and the lateral pelvic regions are easier to examine with a sector probe. The standard frequency range of abdominal transducers is 3.5 to 5 MHz. In obese patients, initial scanning should be done with a 3.5-MHz probe for better penetration.

## Image Orientation in Abdominal Ultrasound

As in gynecologic ultrasound, image orientation is an important consideration in obstetric abdominal ultrasound examinations (19).

**Longitudinal scan.** To ensure uniform orientation, the transducer should be positioned so that the superior portion of the uterus always appears on the left side of the longitudinal scan while the inferior portion is on the right side (Table 1.**4**). Thus, the fetal head always appears to the right of the trunk when the fetus is in a cephalic presentation (Fig. 1.**13**) and to the left of the trunk when the fetus is in a breech

Table 1.**4** Image orientation in abdominal ultrasound

| **Abdominal sagittal scan** | |
|---|---|
| Top of image | = anterior (ventral) |
| Bottom of image | = posterior (dorsal) |
| Right side of image | = inferior (caudal) |
| Left side of image | = superior (cranial) |
| **Abdominal transverse scan** | |
| Top of image | = anterior (ventral) |
| Bottom of image | = posterior (dorsal) |
| Right side of image | = left |
| Left side of image | = right |

presentation (Fig. 1.**14**). In a dorsosuperior transverse lie, the fetal spine appears on the left side of the image (Fig. 1.**15**). In a dorsoinferior transverse lie, the spine appears on the right side.

**Transverse scans.** Transverse scans should have an anatomic orientation with the right side of the maternal abdomen appearing on the left side of the monitor and the maternal left side appearing on the right (Fig. 1.**16**). If the transducer placement is unclear, it can be checked by slipping a finger beneath the side of the probe and seeing if the finger appears on the correct side of the monitor. If not, the transducer should be rotated 180°.

**Fetal position.** For examinations in the second or third trimester, it is important to have a clear mental picture of the topographic position of the fetus, depending on whether the fetus is in a cephalic or breech presentation or transverse lie. This is necessary in order to detect abnormal positions of the fetal organs. In transverse scans, the spinal column of a vertex- or breech-presenting fetus will appear on the right side of the image in the first position and on the left side of the image in the second position.

**Principal scan planes in the fetus.** Three principal planes of section are distinguished in the fetus itself: sagittal, coronal, and transverse (axial) (Fig. 1.**17**). The scan planes necessary for evaluating the fetus are shown in Fig. 1.**18**.

Separate chapters are devoted to more specialized ultrasound techniques, including the various Doppler techniques and 3-D ultrasound.

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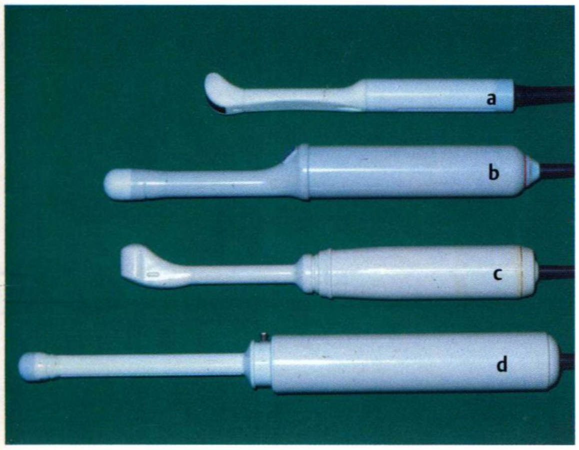
## Transvaginal ultrasound

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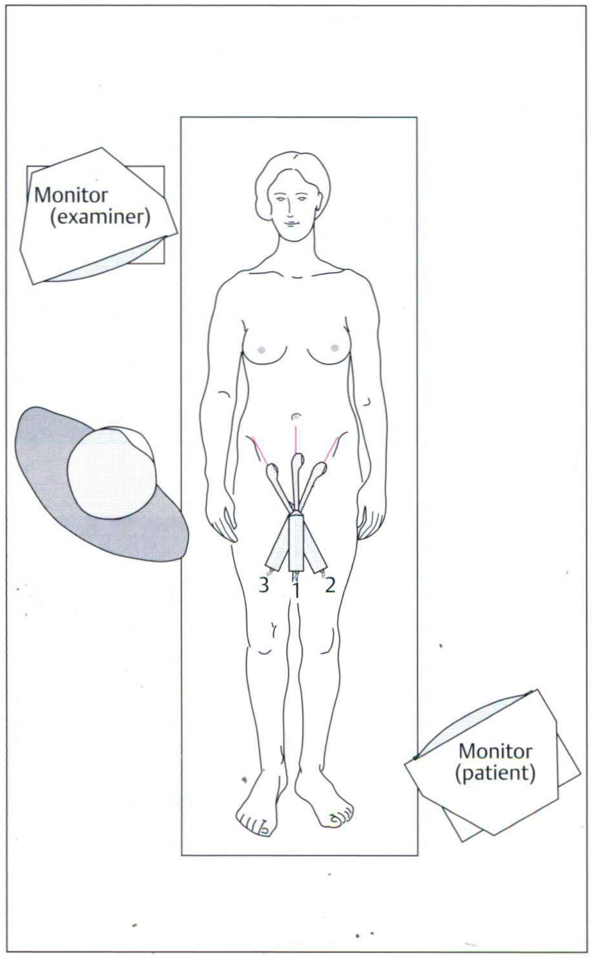


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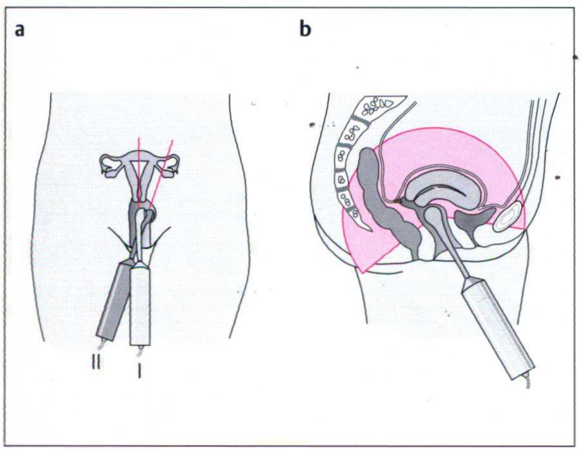


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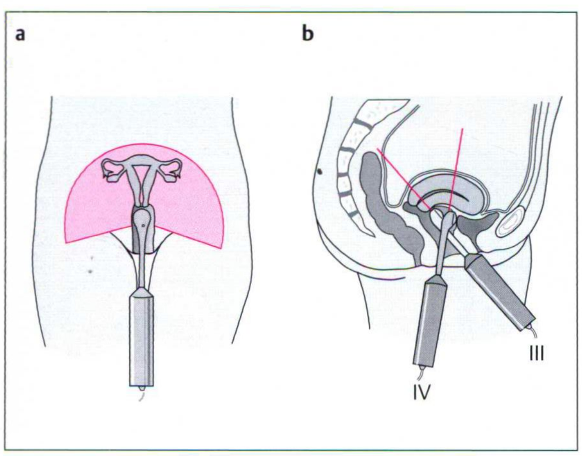


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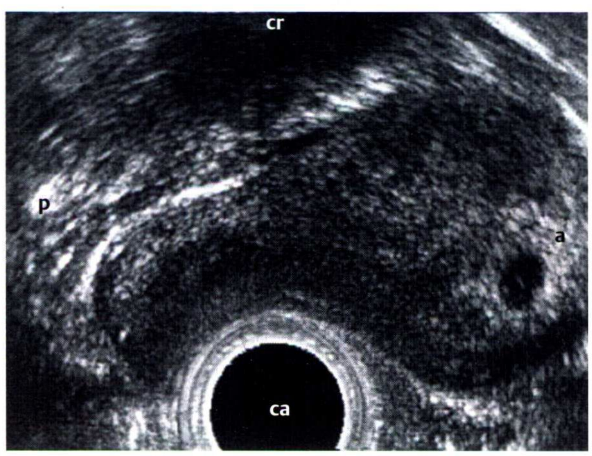


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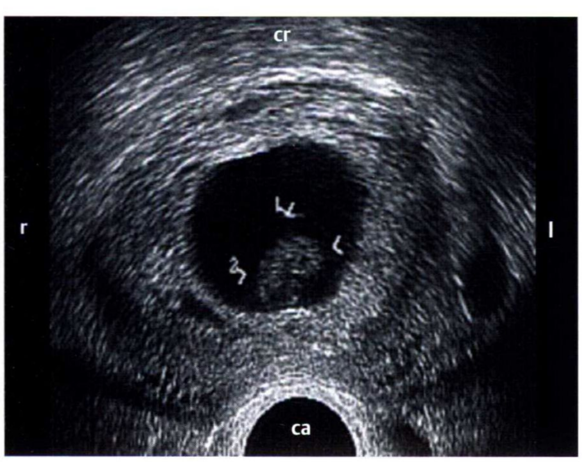


6

Fig. 1.**1** Ultrasound probes for transvaginal use.
**a**, **b** Electronic end-fire probes.
**c** Mechanical panoramic end-fire probe.
**d** Mechanical side-fire probe (chiefly for endorectal use).

Fig. 1.**2** Setup for transvaginal ultrasound on an examination table. The examiner sits to the left of the patient. Separate monitors are provided for the examiner and patient.
1 = Midsagittal scan,
2, 3 = Oblique scans through the lower pelvis.

Fig. 1.**3** Schematic representation of longitudinal scan planes in transvaginal ultrasound with a 240° end-fire probe.
**a** AP view (I = longitudinal midline scan, II = oblique longitudinal scan).
**b** Lateral view of a longitudinal midline scan.

Fig. 1.**4** Schematic representation of coronal scan planes in transvaginal ultrasound with a 240° end-fire probe.
**a** AP view. For clarity, the uterus is shown in a straightened position.
**b** Lateral view (III = transverse scan through the cervix, IV = transverse scan through the uterine corpus).

Fig. 1.**5** Longitudinal scan through a gravid anteflexed uterus at 5 weeks, 5 days. The probe is in the anterior fornix.
cr = superior, ca = inferior,
p = posterior, a = anterior

Fig. 1.**6** Transvaginal coronal scan shows a cross-sectional view of the uterine cavity at 8 weeks, 1 day. The markers indicate the size of the amniotic cavity. A section of the corpus luteum appears on the patient's left side.
cr = superior, ca = inferior,
r = right, l = left