CAMBRIDGE

Cambridge University Press
978-1-107-02974-3 - Ultrasonography in Gynecology
Edited by Botros R. M. B. Rizk and Elizabeth E. Puscheck
Excerpt
More information

Section 1 **Techniques**

Chapter 1

Three-dimensional ultrasonography in gynecology

Norman A. Assad and Sadie Hutson

3D ultrasound in gynecology

Three-dimensional ultrasound (3D US) was first developed by Olaf von Ramm and Stephen Smith at Duke University, Durham, NC in 1987. 3D US imaging extends the diagnostic acumen of the practitioner by providing an additional and very unique tool for the assessment and interpretation of both normal and abnormal pelvic anatomy. The images that are acquired and analyzed enable the operator to gain a perspective that goes beyond the physical examination and images produced by conventional two-dimensional US. The addition of power Doppler in 3D offers an additional clinical assessment of the vasculature of an organ, and may be an important research tool in the ongoing quest to diagnose pathology such as ovarian cancer at a much earlier and potentially treatable stage.

In general, current 3D US imaging systems are based on commercially available, one-dimensional, or annular transducer arrays whose position is known accurately or monitored by a position-sensing device. Position data may be obtained from stepping motors in the scan head, a translation or rotation device, or a position sensor that may be electromagnetic, acoustic, or mechanical. During acquisition, 2D US images and position data are stored in a computer for subsequent reconstruction into 3D US data. Depending on the type of acquisition utilized, the serial slices may be the pattern of a wedge, a series of parallel slices, a rotation around a central axis (i.e. from an endocavitary probe), or arbitrary orientations.

In 2005, the American Institute of Ultrasound in Medicine held a consensus conference on Three- and Four-Dimensional Ultrasound in Obstetrics and Gynecology [1]. The summary stated that 3D US is becoming an important part of state-of-the art sonographic imaging in obstetrics and gynecology. It is a problem-solving tool in selected circumstances. It has the potential to improve practice efficiency and patient throughput without jeopardizing diagnostic capabilities. To become widely accepted, however, work must be done by several groups, including manufacturers, to make the 3D US systems faster and more user-friendly. Additionally, standards must be established for transmission and storage of volume data; educational efforts must be expanded for teaching practitioners how to use and interpret these results. Further, medical societies and the industry need to reach a consensus about how to standardize imaging protocols and display. The panel proposed several recommendations to encourage the use of 3D US for clinical care, teaching, and research in obstetric and gynecologic ultrasound.

Acquisition of volume datasets

With the author's equipment (General Electric [GE] Voluson i) [2], the acquisition of volume datasets is performed by 2D scans with special transducers designed for 2D scans (Fig. 1.1). The 3D sweep and the real-time 4D scans are visualizations of the 3D images in real time. The volume acquisition is started using a 2D image with superimposed VOL-Box or using a 2D+Color image. In the case of a 2D+Color image, the Color-Box is at the same time as the VOL-Box. The 2D start image represents the central 2D scan of the volume. The volume scan itself sweeps from one margin to the other margin of the volume to be acquired. The VOL-Box frames the region of interest (ROI), which will be stored during the volume sweep. The display shows the actual 2D scan.

The sweep time varies and depends on the VOL-Box size (depth, range, and angle) and the quality (six positions). The probe must be held steady and in place during the 3D volume scan. The real-time display of the swept B frames allows continuous observation of the scan quality. During the real-time 4D scan, it is not necessary to hold the probe steady because of the continuous volume acquisition.

The volume scan is automatically performed by a tilt movement of the 2D scan head. The scanned volume is similar to a section of a torus (Fig. 1.2).

3D image rendering

The 3D image rendering is a calculation process to visualize certain 3D structures of a scanned volume via a 2D image. The gray value for each pixel of the 2D image is calculated from

Ultrasonography in Gynecology, ed. Botros R. M. B. Rizk and Elizabeth E. Puscheck. Published by Cambridge University Press. © Cambridge University Press 2015.

© in this web service Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
978-1-107-02974-3 - Ultrasonography in Gynecology
Edited by Botros R. M. B. Rizk and Elizabeth E. Puscheck
Excerpt
More information

Transducer type:

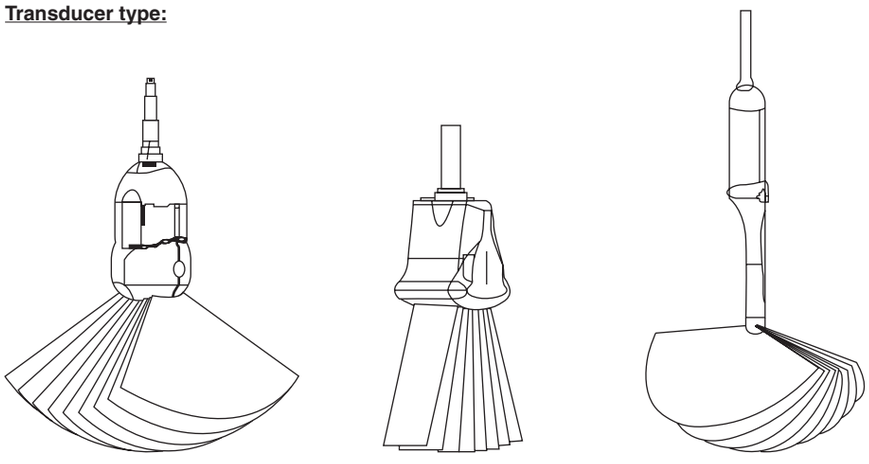

Fig. 1.1 Transducer types.

the voxels along the corresponding projection path (analyzing beam) through the volume. The render (calculation) algorithm surface or transparent mode decides which 3D structures are visualized.

All 3D imaging techniques using a transvaginal probe require that a planar beam of US be swept over the anatomy by use of a 1D transducer array, which is usually mechanical. With 3D ultrasonography, a volume of a target anatomic region, which contains an infinite number of planes, can be acquired. Such volume can then be displayed in three orthogonal 2D planes, representing the sagittal, transverse, and coronal planes of a reference 2D image within the volume. Using various rotations along the X, Y, and Z anatomic axes, the operator has the ability to display any reconstructed 2D plane within the volume. Despite the significant advances offered by 3D US, the acquisition, display, and manipulation of 3D volumes is a technique that requires a substantial learning curve. The ability to automate the retrieval of 2D diagnostic planes out of a 3D volume has significant advantages in clinical practice. This application, which is made available through the advances in 3D ultrasonography, has the potential to allow for an automated display out of a volume of all the 2D planes that are required for a complete anatomic evaluation of the targeted organ within the acquired volume (Fig. 1.3).

In some settings, the manner in which this can be accomplished is by holding a transvaginal probe stationary while the 3D volume is acquired with the push of a button. It is necessary for the patient to remain still during the acquisition of the volume in order to prevent artifacts and distortion. This is particularly important when acquiring power Doppler measurements. The original sweep is done by keeping the acquisition "box" as close to the scanned organ as possible, then on the rendered image any extraneous background can be removed with the Magicut feature (akin to cropping a photograph).

After the 2D US images have been acquired, the 3D US data can be reconstructed. The author's facility uses the GE Voluson

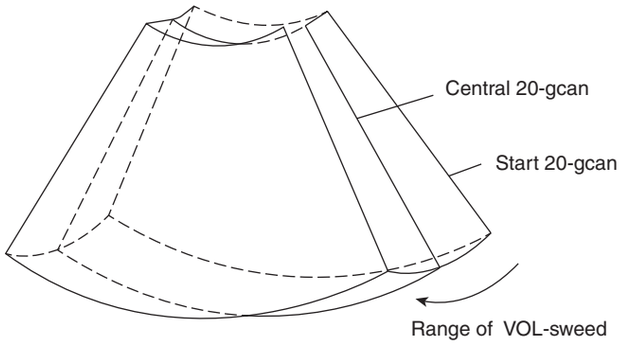

Fig. 1.2 VOL-box: acquisition of the voxel for manipulation on the 3D software.

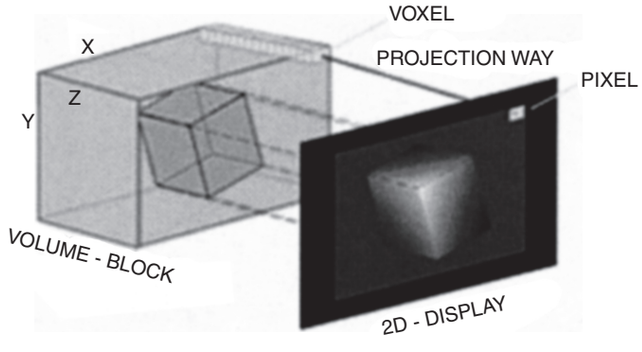

Fig. 1.3 "Voxel box": 3D sweep captures the entire organ being scanned.

i with E8 and 4D view software (4D view) provided by GE and designed by the Kretztechnik Company (Zipf, Austria). One challenge is that the software is only operative with Windows XP. Current modifications will make it compatible for use with Windows 7 software. Most manufacturers of 3D equipment offer their comparable version of software, which is compatible with their specific equipment.

© in this web service Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
978-1-107-02974-3 - Ultrasonography in Gynecology
Edited by Botros R. M. B. Rizk and Elizabeth E. Puscheck
Excerpt
More information

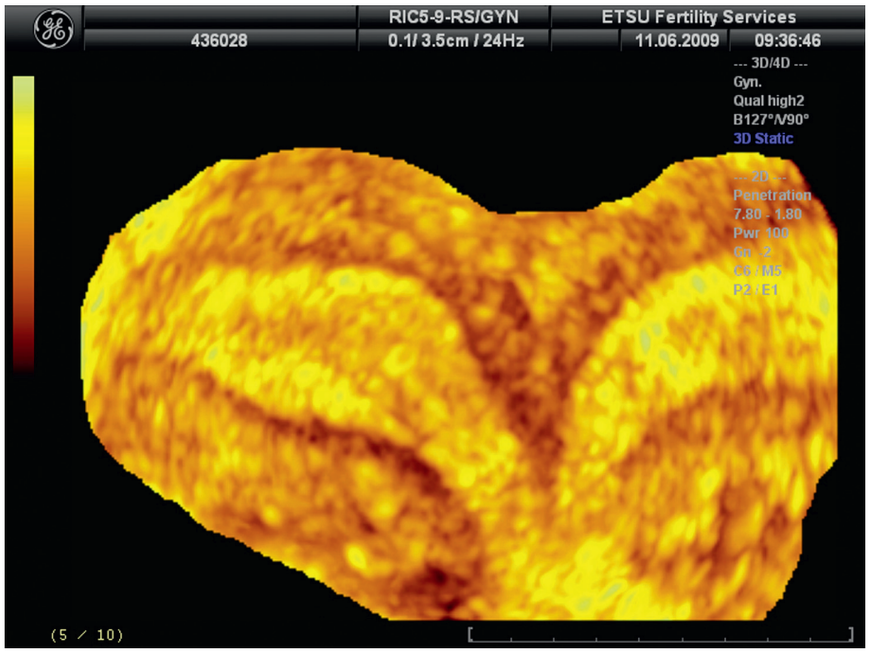

Fig. 1.4 Bicornuate uterus.

Volume data display modes

Volume data can be displayed in three ways: (1) color information alone, (2) grayscale information alone, or (3) a combination of both referred to as "glass body" mode.

Once the images have been rendered on the software, a vast array of features can be determined, including morphologic changes and assessments of color and power Doppler parameters. In addition, the Tomographic Ultrasound Imaging (TUI) feature will allow serial sectioning of the images similar to obtaining tissue slices of an organ in a pathology lab. The slice measurements can be varied. It is also possible to study both uterine and ovarian images using the Inversion Modalities on the software. These include surface rendering of the image – allowing for a more detailed look at the surface contours of a lesion. Image settings include six color settings. Some practitioners prefer to utilize the "candlelight" or "sepia" modalities as this seems to offer optimal visualization. Each individual provider, however, may prefer any of the color settings available with their particular software for optimal visualization of the organ being assessed. Utilizing Virtual Organ Computer-aided AnaLysis (VOCAL), it is possible to accurately determine the volume of an ovary or other pelvic structure. The software allows measurements from 6 degrees to 30 degrees; however, most of the author's assessments utilize the 15-degree parameter. VOCAL 2 software also has a "sphere" modality where power vascular parameters can be measured within a given area. The "Niche" features enable a cutaway of the central portion of an organ. It is also possible to utilize the "Magicut" feature to cut away extraneous images and areas around the focal area of the organ being studied and enables the organ to be "highlighted" for further study. It is then possible to rotate the images between 30 and 60 degrees at 15-degree increments. The axis can be rotated in either the X or Y plane. This is particularly useful to look into the contours of the uterus on study of a coronal plane of the uterus, to examine the details of the vasculature of an ovary, or to study the anatomic details of a fallopian tube.

Using the VOCAL software in 4D endometrial and ovarian volume datasets, Raine-Fenning et al. [3] tested the inter-observer reliability of the results and determined an inter-class correlation coefficient of 0.9 in both organs. The authors concluded that 3D US can reliably be used to acquire, analyze, and define ovarian endometrial volumes.

Specific displays in 3D US

1. *Multiplanar navigation*. The image acquired during the 3D sweep is manipulated on the software to give a coronal view of the uterus. It is then possible to visualize congenital anomalies of the uterus, as well as any pathology, such as uterine fibroids, polyps, intrauterine synechiae, or in the case of a pregnant patient the location of the fetus within the uterine cavity including those pregnancies in an anomalous or abnormal uterus (Fig. 1.4).
2. *Thick slice VCI*. Thick slice VCI allows enhancement of picture quality and the ability to visualize abnormal contours or pathology within the uterus.
3. *Surface rendering*. Surface rendering allows visualization of the organ with varying degrees of contrast and light.
4. *Angiography*. Angiography allows visualization of vessel morphology in both color and power Doppler mode. It is possible to examine vessel aberrations including strictures,

© in this web service Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
978-1-107-02974-3 - Ultrasonography in Gynecology
Edited by Botros R. M. B. Rizk and Elizabeth E. Puscheck
Excerpt
More information

dilatations, "lakes" (pools of color in the image), or orderly versus chaotic vascular patterns.

5. *Inversion*. Inversion mode rendering is a more recently introduced display mode, which starts from the minimum mode rendering and inverts merely the color of the information (similar to negative/positive film), thus presenting the hypoechoic structures as echogenic solids. It blackens most of the surrounding tissue information. By changing certain settings such as increasing the "threshold" and decreasing the transparency, the image can be improved. Choosing either the "gradient light" or the "light" rendering assists in getting the most from the image. This allows some unique views of uterine anomalies and also allows one to visualize antral follicles in the ovary. Two articles published in 2005, Timor-Tritsch et al. and Lee et al. [4,5], describe 3D inversion rendering in gynecology.
6. *X-ray mode*. X-ray mode also allows for visualization of denser structures within the scanned organ; however, the author has found little application for this modality in gynecologic US.

Pelvic organ scanning

It is essential when scanning patients to have a comprehensive medical history regarding their complaints, including the date of the last normal menstrual period. This is required in order to interpret the findings in relation to the day of the menstrual cycle. It is important to be able to distinguish normal anatomic changes from pathologic changes. Frequently, the word "cyst" is utilized instead of "follicle." This can engender much anxiety on the part of patients, who may misinterpret normal findings as "pathologic." It is important for the operator to interpret both uterine and ovarian findings in relation to the day of the cycle in order avoid confusion of normal findings as pathologic. It is also important to know the gynecologic history, obstetrical history, and any other pertinent symptom or history information that could assist in an accurate diagnosis.

Both the uterus and cervix can be rendered in 3D US. More frequently, the addition of the saline sonohysterogram (SIS) enhances uterine findings as it allows for more contrast imaging when interpreting findings. The author routinely uses either a Sonde rigid catheter (Laboratoire C.C.D. Paris, France) or a Gynecath Catheter (Cooper Surgical, Trumbull, CT) for the performance of this test. If possible, the author also prefers to avoid the catheter with a balloon as it is more likely to produce distortion artifact when interpreting 3D US images. Visualizing the coronal plane of the uterus on rendered US images allows for interpretation of a variety of conditions. In 2D studies, SIS is shown to improve the sensitivity, specificity, and positive predictive value in myomas. Further, SIS proved to have both a higher sensitivity than simple transvaginal sonography examination for diffuse lesions and a better specificity for focal lesions. SIS is superior to transvaginal sonography (TVS) in the identification of endometrial polyps in the assessment of hysteroscopic operability of submucosal myomas [6]. SIS can reduce the number of unnecessary diagnostic hysteroscopies and permits a better surgical strategy in selected patients [7,8].

The entire uterus should be scanned in the 3D modality. It is important to keep the rendering box as close to the uterus as possible to exclude any other external artifacts. The angle of scan for a uterus is usually set to 90 degrees.

1. *Congenital anomalies*. The internal contours of the uterus are accurately imaged and allow for visualization of any uterine anomalies, including an arcuate, septate, bicornuate, or uterus didelphys. Uterine anomalies can result in impaired vascularization of a pregnancy and limited space for a fetus due to distortion of the uterine cavity.

   Inversion mode can be utilized with 3D US to give unique imaging in the instance of both unicornuate and bicornuate uteri. Approximately 12–15% of women with recurrent abortion have a uterine malformation. Of all of the possible uterine malformations, complete or partially septate uterus is the most common major anomaly, occurring about one-third of the time; it is associated with the poorest pregnancy outcomes. This anomaly is the most receptive to treatment and successful treatment results in a term delivery rate of 75% and a live birth rate of 85% [9]. The accuracy of diagnosing a septate uterus with 3D US is almost 98% [10].
2. *Uterine pathology*. Polyps and submucosal fibroids can be plainly visualized in relationship to the endometrial surface. In addition to the size and relationship of these pathologic processes to the endometrium, the consistency of the lesion can also be imaged. It is also possible to distinguish between type 0, type 1, and type 2 submucosal fibroids. Submucosal fibroids are by US typically hypoechoic and displace the basalis layer of the endometrium. The amount of extension into the myometrial layer is important in determining the intramural component and in determining the type of surgical procedure to be recommended. Superficial submucosal fibroids with a thin stalk may be removed by a wire loop or alligator forceps, whereas those that extend beyond the endometrial–myometrial interface may be better treated with vaporization or wire loop resection. Fibroids compared with polyps show more heterogeneous echogenicity and more often have a sessile attachment. Polyps tend to have homogeneous echogenicity and have a pedunculated attachment to the uterine wall without interruption of the endometrial lining. Color or power Doppler modes are useful to distinguish myomas from polyps or uterine malignancies. Myomas have a typical vascularization pattern of the capsule, which forms a circle, whereas polyps have a vascular pedicle. Malignancies have an abundant irregular vessel distribution [11] (Fig. 1.5).

© in this web service Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
978-1-107-02974-3 - Ultrasonography in Gynecology
Edited by Botros R. M. B. Rizk and Elizabeth E. Puscheck
Excerpt
More information

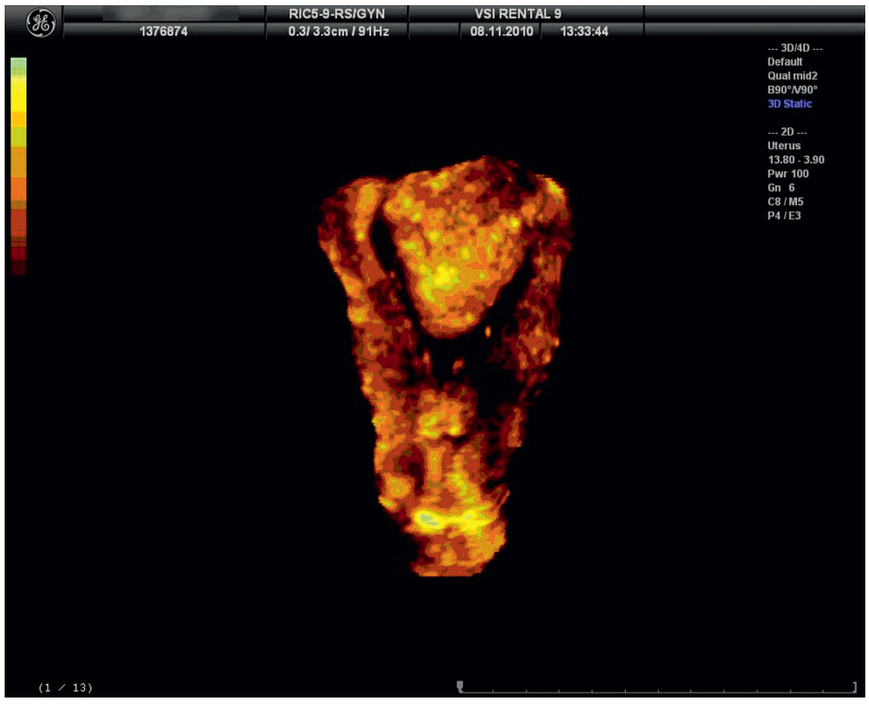

Fig. 1.5 Submucosal fibroid. Type 2.

- 3D US allows for postoperative evaluation of the endometrium to evaluate the results of surgery.
- 3D US also allows for complete visualization of an intrauterine contraceptive device (IUCD) by visualizing the device in the coronal plane.
- 3D US delineates intrauterine synechiae and these images assist the surgeon in preoperative planning when done prior to the surgery. Hysteroscopic treatment of synechiae can markedly improve both menstrual irregularity and reproductive outcome [12].
- 3D US utilizing SIS will also allow for coronal views of the uterus in patients with recurrent miscarriage to insure that there is no other intrauterine pathology or "funneling of the cervix," which may be associated with incompetent cervix.
- 3D SIS can be utilized to evaluate the endometrial changes seen with tamoxifen therapy and give greater detail of the anatomic changes present.
- 3D US can be used to diagnose complications in early pregnancy. These include early diagnosis of ectopic pregnancy, evaluation of the relationship between the gestational sac and uterine septum, and the location of an ectopic pregnancy. It can detect both the presence and volume of a subchorionic hemorrhage, and identify decreased gestational sac volume.

Analysis of the vascular pattern of the endometrium during the menstrual cycle has been described by Raine-Fenning et al. [13]. The study demonstrated that both endometrial and subendometrial vascular flow increased to a maximum 3 days prior to ovulation, then decreased until post-ovulatory day 5, and finally began a gradual increase during the remainder of the luteal phase. The proliferative phase increment was related to estradiol levels and its vasodilating effects, while the luteal phase increase was related to serum progesterone. The flow indices continued to increase during menstruation, regardless of the drastic fall in progesterone levels. This might be explained by the high endometrial vascular density due to progressive compaction of the spiral arteries. The reduction in the post-ovulatory vascular indices is explained by vasodilatation of the subepithelial capillary plexus, which induces the required stromal edema to allow embryo implantation. Therefore, 3D US is a reliable technique for investigating cyclic, physiologic changes in the endometrial vascularization. 3D US allows prompt, integrated evaluation of all known receptivity markers by measuring endometrial thickness, texture, pattern, volume, and global perfusion. While there is currently no reliable ultrasonographic predictor of endometrial receptivity for patients undergoing assisted reproductive technology (ART) (except to predict patients who will have little chance of conception), further comparative studies are needed to establish cut-off values in order to counsel patients about their prognosis regarding endometrial receptivity [14].

3. *Cervical pathology*. Visualization of nabothian follicles, cervical polyps, and endocervical cancer can be made with this modality. 3D US can also be useful in determining the features of a cervical pregnancy. By displaying the "thick

© in this web service Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
978-1-107-02974-3 - Ultrasonography in Gynecology
Edited by Botros R. M. B. Rizk and Elizabeth E. Puscheck
Excerpt
More information

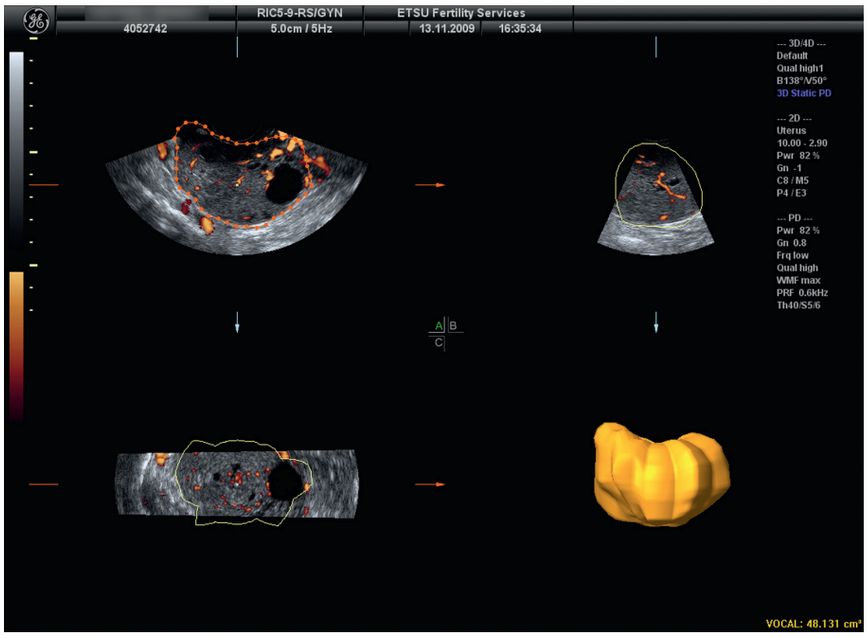

Fig. 1.6 Rendering "power Doppler" scan of ovary to give an accurate volume of that structure.

slice" mode, 3D can enhance the distinct features of the anatomy as well as the chorionic ring. The total separation between the cavity and the ectopic sac becomes more distinct, helping to make the diagnosis. Similar features are useful in diagnosing a cornual or interstitial pregnancy.

4. *Fallopian tube*. 3D scanning allows critical differentiation of the fallopian tube if pathology is involved. Hydrosalpinx has a definitive appearance on 3D ultrasound. After the volume of the tube is obtained, rendering of the images allows the best plane to determine the true nature of the pathology. Demonstration of incomplete septa helps to ascertain that a hydrosalpinx is the appropriate diagnosis. Tubo-ovarian masses can also be more accurately diagnosed using this modality. Using color and power Doppler assists in the diagnosis of tubal torsion; however, this subject will be covered more completely when discussing vascular changes on 3D scanning of the ovary.
5. *Ovary*. 3D evaluation of the ovary brings a unique perspective to the interpretation of pathology. Several modalities can be studied in order to gain information regarding pathologic or growth parameters within the ovary. While scanning the ovary it is necessary to keep the rendering box as close to the ovary as possible to rule out any extraneous artifacts. Most 3D sweeps through the ovary are done at the 60-degree setting on the ultrasound machine.

   The first modality that is evaluated is the morphology of the ovary. Morphologic assessment by 3D US yields additional information over that of 2D scans.While endometriomas, benign cystic teratomas, and theca lutein cysts have a specific appearance on 2D scans, the unique features of malignancy are visualized in more detail utilizing 3D modality. The latter allows the ability to look inside the cyst and study the surface changes in more detail (Figs 1.6 and 1.7).

   Features to be evaluated in an ovary to distinguish malignancy include the thickness of wall structures. Goldstein and Timor-Tritsch [15] use an arbitrary cut-off of 4 mm to distinguish lesions that are more likely to be malignant. Septation and loculation is also another finding that can raise the suspicion for malignancy. Multilocularity is more common in tumors of low malignant potential and malignant neoplasms. Papillations are also significant in assessing the morphology of the ovary and are more suspicious for malignant neoplasms. Papillae that contain blood vessels with detectable flow are more suspicious for malignancy. Exacoustos et al. [16] found that papillae as large as 15 mm in height and 10 mm in width were present in 48% of borderline tumors, but in only 4% of benign and 4% of malignant tumors. However, when papillations were larger, the lesions were present in 48% of invasive ovarian tumors, 18% of borderline tumors, and 7% of benign masses. Internal echo structure can indicate the present of particulate matter such as blood, cellular matter, or even mucoid material. A mass with mixed echogenicity can been found in either teratomas or malignancy. Shadowing, if present, may suggest the presence of an extremely dense tissue such as bone or calcification, indicating the probability of a benign teratoma. Malignant masses very rarely display frank shadowing.

   In general, the larger the lesion, the more suspicious it is for malignancy. Malignant tumors usually have a complex appearance with thick walls greater than 4 mm, as well as a heterogeneous texture, multilocularity, solid

© in this web service Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
978-1-107-02974-3 - Ultrasonography in Gynecology
Edited by Botros R. M. B. Rizk and Elizabeth E. Puscheck
Excerpt
More information

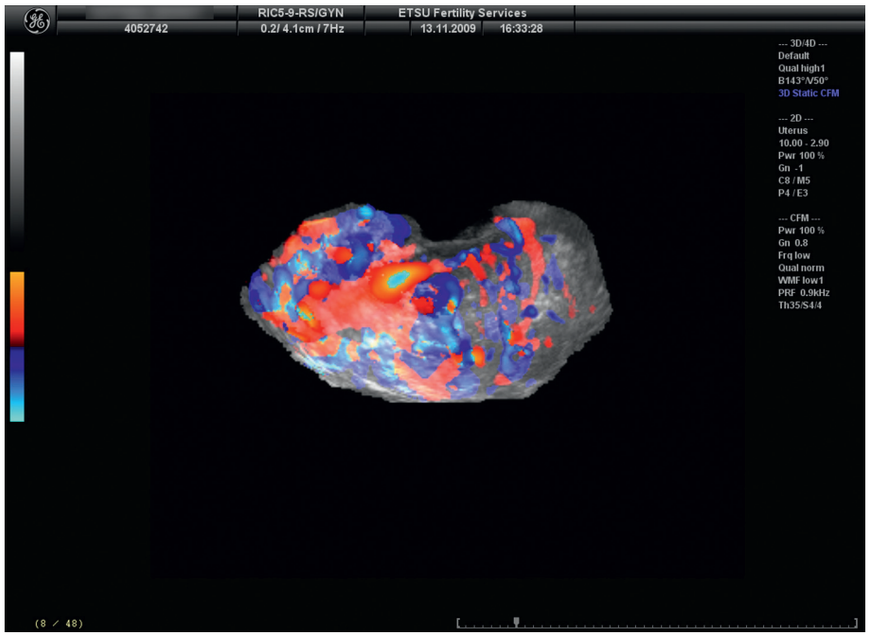

Fig. 1.7 Color Doppler acquisition of ovary showing "beach ball structures, strictures, and loss of tree-like vascularity" [32]. This lesion was a granulosa cell tumor of the ovary.

components, and papillary excrescences, particularly those demonstrating a lush blood supply. Timmerman and colleagues [17] published a report that illustrated five simple rules to predict malignancy: (1) irregular solid tumor, (2) ascites, (3) at least four papillary structures, (4) irregular multilocular-solid tumor with a largest diameter of at least 100 mm, and (5) very high color content on color Doppler examination. Five simple rules suggested a benign tumor: (1) unilocular cyst, (2) presence of solid components, where the largest solid component is less than 7 mm in largest diameter, (3) acoustic shadows, (4) smooth multilocular tumor less than 100 mm in largest diameter, and (5) no detectable blood flow on Doppler examination.

According to a technology assessment from the Agency for Healthcare Research and Quality (AHRQ), "conventional gray-scale ultrasonography is the most common imaging modality used to differentiate benign from malignant adnexal masses." Hopefully, 3D US using some of the study material displayed below will help to assist in the differentiation of benign from malignant lesions.

An opinion from the International Ovarian Tumor Analysis (IOTA) group regarding the terms, definitions, and measurements to describe the sonographic features of adnexal tumors [18] is described in this article.

Sensitivity and specificity of multimodal and ultrasound screening for ovarian cancer and stage distribution of detected cancers were published in the UK Collaborative Trial of Ovarian Cancer Screening (UKCTOCS) [19] and the results were encouraging as the sensitivity of the multimodal screening (MMS) was greater than the ultrasound screening (USS) group, resulting in lower rates of repeat testing and surgery. This in part reflects the high prevalence of benign adnexal abnormalities and the more frequent detection of borderline tumors in the USS group.

Amor et al. [20] described a Gynecologic Imaging Reporting and Data System that showed good diagnostic performance. The system is simple and could facilitate communication between sonographers/sonologists and clinicians.

3D power Doppler angiography

3D power Doppler angiography is a sonographic angiogram created by power Doppler-based identification of the blood flow of the vascular tree, where the vessel diameter is about 0.5–1 mm and blood velocity exceeds 2–3 mm per second [21].

For power Doppler scans, the author sets the Quality at high, the wall motion filter (WMF) at low, and the pulse repetition frequency (PRF) at 0.9. The scanning angle for ovaries is generally set at 60 degrees. These settings are used for scanning a known lesion. However, for screening, it has been suggested that the WMF is set to maximum. Unfortunately, the literature is confounded by the lack of standardization of settings, which can differ even within the 3D equipment of one manufacturer, much less the variation that occurs between different vendors and operators. Further research is urgently required in order to determine power Doppler parameters for the "normal" population. After the image is acquired, the render mode is then utilized to visualize the vessels in the entire volume after the color option is selected. Programs such as VOCAL software can be used to outline the contour of the ovary. Next, press the "Manual" button, followed by the degree tracing (6, 9, 15 or 30 degrees). Customarily, 15 degrees is utilized followed

© in this web service Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
978-1-107-02974-3 - Ultrasonography in Gynecology
Edited by Botros R. M. B. Rizk and Elizabeth E. Puscheck
Excerpt
More information

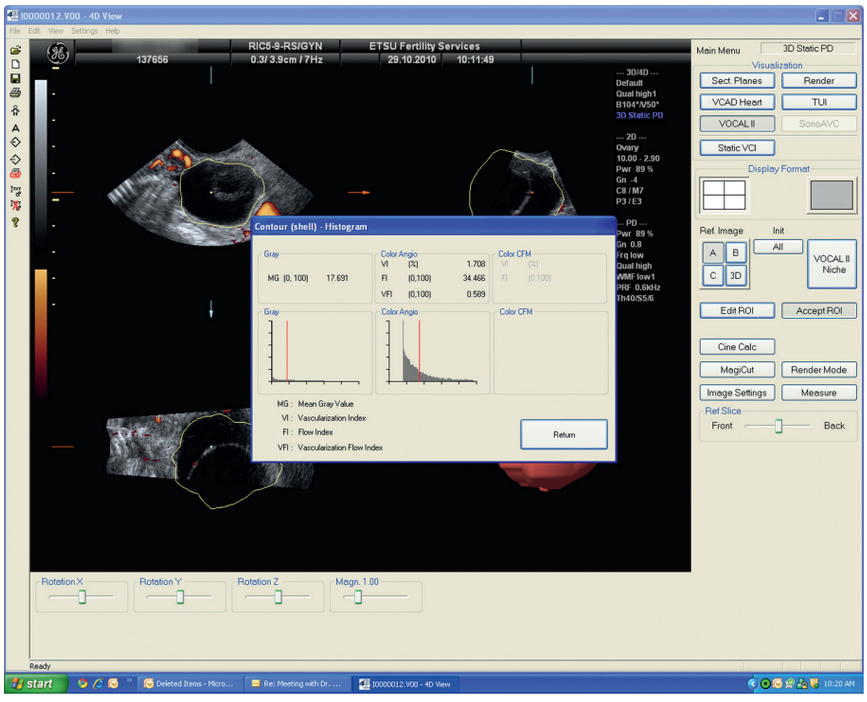

Fig. 1.8 . Histogram of the ovary documenting VI, FI, and VFI.

by employing the trace feature on the software to outline the ovary at each rotation. When the process is complete a volume shell of the ovary is displayed along with the volumetric assessment and size of the organ. From there it is possible to render the structure by the aforementioned "glass body" appearance, which then allows the user to visualize the vasculature within the ovary, display the vessels in the structure, or activate the histogram button on the software to give the various vascularization indices of the ovary. These are expressed as the vascularization index (VI), the flow index (FI), or the vascularization flow index (VFI) as a percentage between 1% and 100% (Fig. 1.8).

- The VI [22] represents the vessels in the tissue and is important in diagnosing high and low vascularization.
- The FI, a mean amplitude value, is important to characterize high-flow intensities that are seen more often in malignant tumors.
- The VFI is a combination of VI and FI, and identifies the extremes between low vascularization and low blood flow versus high vascularization and high blood flow.

Although VI and FI showed excellent reproducibility, VFI did not achieve accurate estimation between two observers, which might lead to unreliable measurements. In the future with further research there may be better evidence as to whether the VI and FI will become good predictors for neovascularization. This could then replace qualitative or semi-quantitative 3D power Doppler evaluations. Technologic developments, application of new indices for quantification of vascularization and blood flow using the cube method, and simultaneous Doppler shift spectrum analysis will hopefully increase the usefulness of these new modalities.

Combining power Doppler and 3D tissue vascularization can be studied. Once the organ volume has been determined then the histogram produces various indices such as the VI, the FI, and the VFI.

A non-malignant source of morbidity involving the ovary is adnexal torsion. There is some suggestion that the diagnosis might be enhanced with power Doppler studies. Fleischer [23] has described changes consistent with adnexal torsion. These include detection of central flow, which is associated with still viable adnexa, and flow which is not present in the mass but in the capsular area around the mass. The "pedicle" sign [24,25] has been described and consists of color or power Doppler imaging of a spiral arrangement or coiling of the blood vessels that is highly suggestive of torsion of the fallopian tube or ovary. While not always present, when seen it is highly diagnostic for torsion.

Traditionally in 2D US scans, transvaginal color Doppler imaging allows tumor vascularization assessment. With publication of the study by Kurjak et al. in 1991 [26] there was hope that a resistance index (RI) of less than 0.4 would differentiate between benign and malignant masses. Fleischer et al. [27], in a group of ovarian masses using pulsatility index (PI) of less than 1 as the cut-off, found a sensitivity of 100% and a specificity of 83% with a positive predictive value of 73%. However, subsequent papers have failed to validate the predictive values of color flow assessment in ovarian tumors. There is no good published evidence that color or power

© in this web service Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
978-1-107-02974-3 - Ultrasonography in Gynecology
Edited by Botros R. M. B. Rizk and Elizabeth E. Puscheck
Excerpt
More information

Doppler can be used to detect ovarian cancer in either premenopausal or postmenopausal women with normal-sized ovaries. Morphologic assessment of the ovaries with both 2D and 3D modalities continues to be scrutinized in an attempt to increase the likelihood of early detection and/or screening of ovarian cancer [28].

Various authors have endeavored to increase the sensitivity and specificity of diagnosis of ovarian carcinoma. Some major contributors include, but are not limited to, the following:

- In a study by Kurjak et al. [29], morphologic analysis by 3D US alone detected 74% of cancers ($N = 90$). Adding Doppler evaluation of tumor vascularity predicted 41 cases of stage 1 ovarian cancer, a 95.4% detection rate. Combined morphologic and 3D Doppler findings achieved a diagnostic accuracy of 97.7% [30].
- Chase et al. [31] published results of their study of preoperative diagnosis of ovarian malignancies using 3D vascular US. In this preliminary and observational study, chaotic vascular architecture correlated with malignancy in this group of high-risk patients.
- Crade [32] used a "Tissue Block" of data to analyze a variety of vascular features. These included loss of "treelike" branching of vessels, sacculation of arteries and veins, focal narrowing of arteries, internal shifts in velocity within arterial lumen, and the "Beach Ball" finding of abnormally increased and disorganized peripheral flow. Also noted was increased flow to the center of a solid region, crowding of vascularity and "start" and "stop" arteries found within a mass in a disjointed fashion losing the "tree-like" branching.
- Cohen et al. [33] concluded that 3D power Doppler evaluation defined the morphologic and vascular characteristics of ovarian lesions significantly better than 2D US alone. Specificity was significantly improved by the additional of 3D power Doppler analysis.
- Sladkevicius et al. [34] investigated the contribution of morphologic assessment of the vessel tree by 3D US to a correct diagnosis of malignancy in ovarian masses. The study concluded that subjective evaluation of the morphology of the vessel tree as depicted by 3D power Doppler US can be used to discriminate between benign and malignant tumors, but adds little to grayscale imaging in an ordinary population of tumors.
- Alcazar et al. [35] in an article entitled, "Three-dimensional sonographic morphologic assessment of adnexal masses: a reproducibility study" concluded that 3D sonography is a reproducible technique for morphologic assessment of adnexal masses.
- Other authors [36,37] have used "micro-bubble" (e.g. using harmonics or phase inverse imaging on grayscale or transient responses) enhanced sonography to depict microvessel perfusion. These techniques may allow assessment of tumor blood flow and changes that occur with treatment.
- Fleischer et al. [38] in an article entitled, "Contrast-enhanced transvaginal sonography of benign versus malignant ovarian masses," concluded that there was a significant difference in the contrast enhancement kinetic parameters between benign and malignant ovarian masses using "micro-bubble" technology.
- Prior to that, Marret et al. [39] showed that contrast-enhanced power Doppler imaging may easily and precisely discriminate benign from malignant adnexal lesions. Levomist was used in these studies.
- Several authors [40–42] have also used logistic regression analysis to further define the probability of malignancy in women with pelvic masses. Several prognostic variables were used in these articles to assess whether accuracy is better with a combination of variables than with the morphological Doppler criterion alone. This analysis shows promise and further studies are ongoing.
- Alcazar and Castillo [43] concluded that 3D power Doppler imaging did not have a better diagnostic performance than 2D power Doppler imaging for the discrimination of benign from malignant complex adnexal masses. However, another group of authors [44] concluded that evaluation by 3D US did improve the diagnosis of ovarian tumors.
- Kudla et al. [45] and Alcazar et al. [46,47] have utilized virtual spherical tissue sampling using 3D US power Doppler angiography to enhance differentiation between normal and pathologic ovaries. All three studies concluded that spherical sampling is a sensitive and promising approach to differentiate between ovarian tumors and normal ovaries. The most recent study from Alcazar depicted that 3D power Doppler vascular indices could be helpful for reducing the false-positive rate in cystic-solid and solid, vascularized adnexal masses [47].

The absolute critical values for these parameters (VI, VFI, and FI) remain to be determined; however, the higher the indices when interpreted in tandem with the morphologic changes in the ovaries, the greater the suspicion for ovarian carcinoma.

The utility of 3D US in the diagnosis of ovarian carcinoma is controversial and lacking in universal agreement. It has been established, however, that the morphology of both the ovaries and vasculature can be enhanced with this technology. When combined with an increase in the vascular parameters measured on the "histogram," the index of suspicion is enhanced with an increase in the vascularity of the lesion.

The morphologic structure of the blood vessels might also yield some valuable insight into the presence of a malignant lesion, particularly where a disordered pattern is noted. With the development of new and more sensitive probes such as matrix volume probes, it may be possible to study the microvasculature of the ovary in greater detail.

Undoubtedly, 3D US enhances the number of ways an ovary can be studied and each modality studied can yield another layer

© in this web service Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
978-1-107-02974-3 - Ultrasonography in Gynecology
Edited by Botros R. M. B. Rizk and Elizabeth E. Puscheck
Excerpt
More information

of information when attempting a diagnosis. Traditional ways of discriminating benign from malignant lesions as described in 2D US cannot be discounted, but merely enhanced by the further information gleaned from 3D assessment of the various parameters. Hopefully, ongoing research with this valuable tool will yield novel ways of studying the ovary in greater detail and subsequently inform more accurate and earlier diagnosis of serious pathology.

One of the most important steps is to determine the normal power Doppler parameters in both the pre- and postmenopausal population. The data are further confused by the different equipment and different machine parameters even within the equipment of the same manufacturer. Research is currently underway to determine the key settings to obtain the maximal information regarding the microvascularity of an organ, with particular reference to the ovary.

Conclusion

3D US of the pelvic organs provides an invaluable tool for enhancing diagnosis and, it is to be hoped, will result in more favorable outcomes for patients.

The findings of uterine anomalies as well as cervical and tubal pathology are greatly enhanced with this modality at a fraction of the cost, time, and inconvenience of an MRI. The scan times for the patients are quick and subsequent analysis can be done by the physician at a later time. The same holds true for cervical and tubal pathology. Most of the time, the patient can be informed of her results on the day of the scan, resulting in less patient anxiety and reduced wait-times for results.

While this tool is valuable for assessing vascular abnormalities, there is still untapped potential regarding the enhanced accuracy of diagnosing ovarian pathology. Hopefully, with technologic advances in equipment and software in the coming years, we will see major breakthroughs in the early diagnosis of ovarian cancer. Future research is required in order to provide a standardized protocol that can be developed for the advanced imaging of the ovaries.

Although the learning curve with this technology is long, the returns in the accuracy of the imaging obtained are well worth the effort.

Acknowledgments

The authors would like to express gratitude to Dr. Ilan Timor-Tritsch for his generous contribution of time in enhancing the skills of Dr. Norman Assad with the 3D US techniques described herein. Thanks also go to Sadie Hutson PhD for the many contributions to this chapter.

References

1. Benacerraf M, Benson CB, Abuhamad AZ, et al. Three and 4-dimensional ultrasound in obstetrics and gynecology: proceedings of the American Institute of Ultrasound in Medicine Consensus Conference. *J Ultrasound Med* 2005; **24**: 1587–1597.
2. GE Healthcare: Basic User Manual. Voluson i. Revision 2. KTI 106029–100.:10.1.1–10.1.2.
3. Raine-Fenning NJ, Campbell BK, Clews JS, et al. The interobserver reliability of three-dimensional power Doppler data acquisition within the female pelvis. *Ultrasound Rev Obstet Gynecol* 2004; **23**: 501–508.
4. Timor-Tritsch IE, Monteagudo A, Tsymbal T, Strok I. Three-dimensional inversion rendering. A new sonographic technique and its use in gynecology. *J Ultrasound Med* 2005; **24**: 681–688.
5. Lee W, Gonçalves LF, Espinoza J, Romero R. Inversion mode: a new volume analysis tool for 3-dimensional ultrasonography. *J Ultrasound Med* 2005; **24**: 201–207.
6. Cohen LS, Valle RF. Role of vaginal sonography and hysterosonography in the endoscopic treatment of uterine myomas. *Fertil Steril* 2000; **73**(2): 197–203.
7. Goldstein S. Saline infusion sonohysterography. *Clin Obstet Gynecol* 1996; **39**: 248–258.
8. Widrich T, Bradley LD, Mitchenson AR, Collins RL. Comparison of saline infusion sonography with office hysteroscopy for the evaluation of endometrium. *Am J Obstet Gynecol* 1996; **174**: 1327–1334.
9. Grimbizis GF, Camus M. Tarlatzis BC, et al. Clinical implications of uterine malformations and hysteroscopic treatment results. *Hum Reprod Update* 2001; **7**(2): 161–174.
10. Kupesic S. Three-dimensional ultrasound in reproductive medicine. *Ultrasound Rev Obstet Gynecol* 2005; **5**: 304–315.
11. Diagnosing the submucosal fibroids (SIS). Beyond Hysterectomy: The Contemporary Management of Uterine Fibroids – An International Conference; April 11–13, 2003.
12. Valle RF, Sciarra JJ. Intrauterine adhesions: hysteroscopic diagnosis, classification, treatment, and reproductive outcome. *Am J Obstet Gynecol* 1988; **158** (6 Pt 1): 1459–1470.
13. Raine-Fenning NJ, Campbell BK, Kendall NR, et al. Quantifying the changes in endometrial vascularity throughout the normal menstrual cycle with three-dimensional power Doppler angiography. *Hum Reprod* 2004; **19**: 330–338.
14. Alcazar JL. Three dimensional ultrasound assessment of endometrial receptivity: a review. *Reprod Biol Endocrinol* 2006; 456.
15. Timor-Tritsch IE, Goldstein SR. Skilled US imaging of the adnexae Part 2: the non-neoplastic mass. *Obg Management* 2010; **22**(10): 2–8.
16. Exacoustos C, Romanini ME, Rinaldo D, et al. Preoperative sonographic features of borderline ovarian tumors. *Ultrasound Obstet Gynecol* 2004; **25**(1): 50–59.
17. Timmerman D, Testa AC, Bourne T, et al. Simple ultrasound-based rules for the diagnosis of ovarian cancer. *Ultrasound Obstet Gynecol* 2008; **31**: 681–690.
18. Timmerman D, Valentin L, Bourne TH, et al. Terms, definitions and measurements to describe the sonographic features of adnexal tumors: a consensus opinion from the International Ovarian Tumor Analysis (IOTA) Group. *Ultrasound Obstet Gynecol* 2000; **16**: 500–505.
19. Menon U, Gentry-Maharaj A, Hallett R, et al. Sensitivity and specificity of multimodal and ultrasound screening for ovarian cancer, and stage distribution of detected cancers: results of

© in this web service Cambridge University Press www.cambridge.org