The Use of Three-dimensional Ultrasound in Gynecological Patients

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Abstract: Two-dimensional ultrasound is commonly used in gynecologic patients. It has been shown to be very useful for diagnosing pelvic pathology in both asymptomatic and symptomatic patients. Three-dimensional ultrasound is a new imaging modality, which is being introduced into clinical practice. Although this technique will not probably replace two-dimensional ultrasound, it is being increasingly used. It has been reported that 3DUS is a very high reproducible technique that may have applications in the field of gynecology. These applications include imaging of the uterus, uterine cavity, adnexa and pelvic floor, as well as very interesting applications using three-dimensional power-Doppler ultrasound. The aim of this paper is addressing some technical features of three-dimensional ultrasound and reviewing its current status in clinical practice.

Keywords: Two-dimensional, three-dimensional, ultrasound, gynecology.

INTRODUCTION

Two-dimensional ultrasound (2DUS) is widely used in gynecological patients and its diagnostic role has been well-established. However, some limitations for this technique still exist. For example, 2DUS is highly operator dependent, obtaining some planes such as coronal plane of pelvic structures is quite difficult in most circumstances and may be time-consuming.

Three-dimensional ultrasound (3DUS) has been introduced in clinical practice in the last decade. Clinical applications for this technique in gynecology are being increasingly reported.

This new technology is based on the quality of 2DUS. This means that high 2DUS quality is required for obtaining a high quality 3DUS. On the other hand, this technique is also highly dependent on software advances. Three-dimensional ultrasound allows off-line assessment of 3D reconstructed volumes without being the patient present, is less time-consuming for patient examination and may increase the efficiency of ultrasound.

What may add 3DUS? This technique allows unique ways for assessing the gynecological patient, such as: Virtual navigation, volume organ computer aided analysis (VOCAL), tomographic ultrasound imaging (TUI), speckle reduction imaging (SRI), volume contrast imaging (VCI), inversion mode and automated volume calculation (Sono-AVC)

In the present article I shall review some technical and methodological aspects of 3DUS as well as to introduce some clinical applications of this new technique for assessing the gynecological patient.

TECHNICAL CONSIDERATIONS

There have been published several papers that have dealt in detail with technical aspects of 3DUS.[1-3] 3DUS images can be obtained by two methods: Freehand and automated. The freehand method requires manual movement of the transducer through the ROI. This method can be used in both on-line and off-line systems. In the in-line system image acquisition, storage and manipulation are all done within the same ultrasound machine. The off-line system uses an analog video output from the ultrasound unit. The latter system has less resolution than the on-line system. The main drawback of all freehand systems is that measurements are not as accurate as with automated 3D transducers, and image quality uses to be worse.

The automated method acquires the images using dedicated 3D transducers. When these probes are activated, the transducer elements automatically sweep through the ROI selected by the operator (the so-called volume box) while the probe is held stationary. The operator can select a constant speed of sweep through the ROI using machine settings. The lower the speed, the higher is the resolution. The larger the volume box, the longer is the acquisition time. This provides more accuracy to this method as compared with the freehand systems, in which speed of sweep is more difficult to maintain constant manually by the operator.

Acquired images using the automated method may be processed within the ultrasound machine or in an off-line workstation. The digitally stored volume data can be manipulated and presented in various displays: Multiplanar display, "niche" mode or surface rendering mode. In Gynecology, probably, the most used and useful display is

multiplanar display, which simultaneously shows three perpendicular planes (axial, sagittal and coronal), allowing navigation through these three planes with the possibility of switch over any desired plane.

Another important ability of 3DUS is volume calculation using the Virtual Organ Computer-aided AnaLysis (VOCAL) even in irregularly-shaped structures.[4]

Vascularization of tissues within the ROI can be also assessed using 3D Power-Doppler ultrasound (3DPD) and the VOCAL program.[5] Using this method, three vascular indexes can be calculated: The vascularization index (VI), expressed as percentage, measures the number of color voxels in the studied volume, representing the blood vessels within the tissue. The flow index (FI) is the average color value of all color voxels, representing average color intensity. And the vascularization flow index (VFI) is the simple mathematical relationship derived from multiplying VI by FI and dividing the result by 100.

Artifacts may be present when using 3DUS. Some of them are the same than in 2DUS, such as acoustic shadowing, reverberation and motion artifacts. Some others are unique to 3DUS and may be derived from acquisition, rendering or editing.[6]

METHODOLOGICAL CONSIDERATIONS

For assessing gynecological patients transvaginal or transrectal routes should be preferred. Transperineal route is quite useful for assessing the pelvic floor.

One question absolutely relevant before performing 3DUS scanning is to properly adjust both gray-scale B-mode and power Doppler settings. Although to date no international consensus about this question has been reported, the Spanish Society of Ultrasound in Obstetrics and Gynecology has published a report with B-mode and power Doppler settings recommendation to be used.[7] The use of these settings is especially advisable when performing research on order to obtain comparable and reproducible results.

When performing 3DUS in a gynecological patient it is recommended to adjust the 3D box for including the whole uterus in one volume and the adnexal regions in two additional volumes, one per right and another per left ovaries. In our experience uteri larger than 250 ml are difficult to include in just one single 3D volume (Alcázar, personal communication). 3D-sweep angle should be 90º and two sweeps are recommended: One in longitudinal plane and other in transverse plane.

There are some reports about the standardization of the technique.[8,9]

VALIDATION OF THE TECHNIQUE

Three-dimensional ultrasound allows calculating volume as well as to assess ROI vascularization.

Several studies have demonstrated that this technique is accurate for measuring volume,[10,11] being the VOCAL rotational method the most exact method.[12] This method is reliable for measuring volumes of both regular and irregular shaped structures.[13] This method has been demonstrated to be more accurate than 2D-volume estimation.[14] Furthermore, this method has been reported to be very accurate for estimating endometrial volume.[15]

However, the accuracy of the method depends on some scanning conditions such as focus and object depth.[16]

Regarding 3D vascular indexes, in a phantom study it was shown that VI, FI and VFI correlate with the number of vessels and flow but machine settings affect measurements.[17] Some other studies have found a correlation between VI and histological microvessel density measured by immunohistochemical techniques.[18,19]

REPRODUCIBILITY

One of the main problems while using 2DUS is its reproducibility, both for volume and Doppler measurements. Three-dimensional ultrasound has been demonstrated to be a very reproducible technique.

Several studies have shown that 3DUS has a very low inter-observer and intraobserver variability for calculating endometrial and ovarian volume,[20] but depends on the technique used,[20] as well as for estimating ovarian and endometrial vascularization using 3D PD.[21-23]

VIRTUAL NAVIGATION

One of the most useful tools provided by 3DUS is virtual navigation. Using this tool we are able to "navigate" through the organ under study. This navigation allows the examiner to determine in real time much better spatial relationships among structures. This could be useful for assessing uterine congenital malformations, submucous myomas or endometrial polyps (Fig. 1).

TOMOGRAPHIC ULTRASOUND IMAGING (TUI)

TUI allows a picture display similar to that obtained by CT scan or MRI. This method also allows a more precise analysis of spatial relationships among structures under study. In contrast to CT scan or MRI, slice thickness may be modified according to examiner desire after acquiring the 3D volume.

It is thought that this method could be useful for assessing uterine pathology (Fig. 2).

SPECKLE REDUCTION IMAGING (SRI)

SRI is a new tool that allows a better contrast resolution providing a better quality image. It is interesting to know that this tool can be used during the post-processing analysis of the image, e.g. after acquiring the 3D volume (Fig. 3).

Fig. 1: Three-dimensional image that show three orthogonal planes of a uterus with submucous myoma. Virtual navigation allows a precise location of the myoma and its relationship with uterine cavity serosa

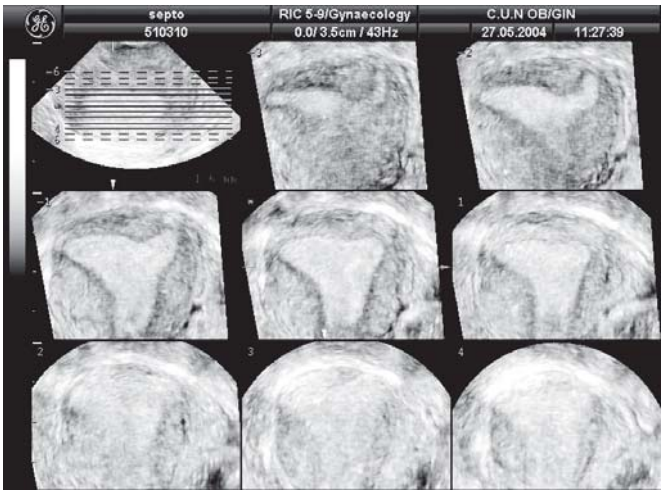
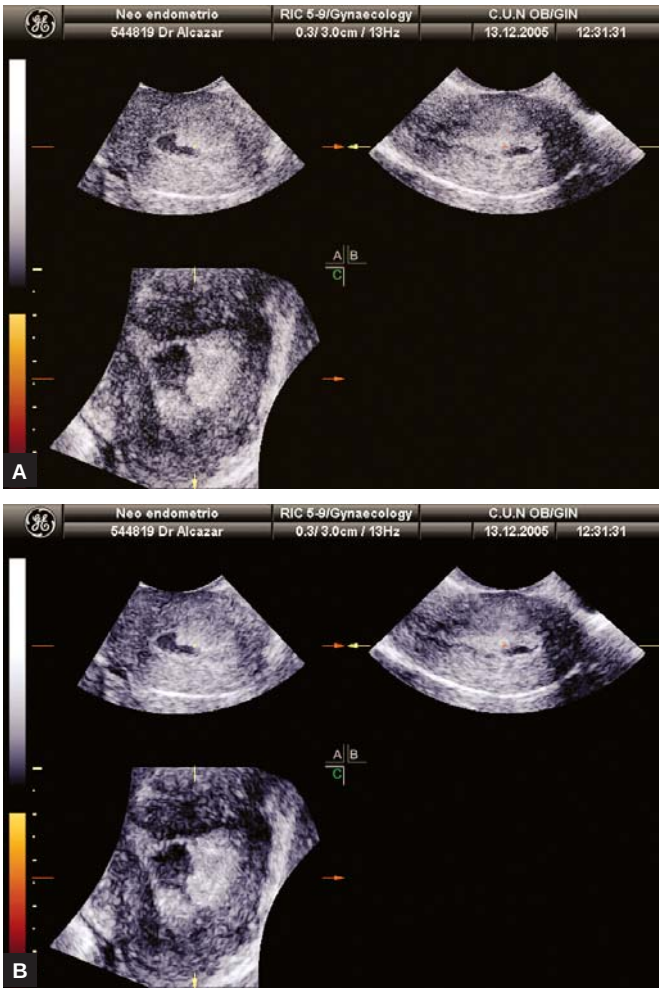


Fig. 2: Tomographic Ultrasound Imaging (TUI) of a coronal plane from an uterus showing a congenital müllerian anomaly, probably a left hypoplastic cornu



Figs 3A and B: Speckle Reduction Imaging (SRI) from an uterus. Please, note how initial image (A) changes after SRI is used (B). The new image is softer and speckling is reduced

It is thought that this tool could be useful for better analyzing tissue interfaces, for example myometrial-endometrial interface.

VOLUME CONTRAST IMAGING (VCI)

VCI also allows an improvement of contrast image (Fig. 4). Using this tool the examiner could assess better diffuse lesions such as adenomyosis.

RENDER MODE

This tool allows assessing structure's surfaces. In gynecology can be useful for assessing internal surfaces of adnexal lesions such as ovarian or the surface of the endometrium during sonohysterography (Figs 5 and 6).

Render mode also allows reconstructing three-dimensionally the vascular network of the organ under study (Fig. 7). This has been shown to be a promising and reproducible tool for assessing adnexal masses vascularization.[24, 25]

VIRTUAL ORGAN COMPUTER-AIDED ANALYSIS (VOCAL)

This is a rotational method that allows volume and vascularity calculation. It has been shown to be very accurate for assessing uterine, endometrial and ovarian volume[12] (Figs 8 and 9).

This method is actually under investigation in gynecologic fields such as infertility,[26,27] assisted reproductive techniques,[28,29] primary dysmenorrhea,[30] adnexal masses[31,32] and endometrial pathology.[33]

Figs 4A and B: Volume contrast imaging (VCI) from the same case than figure 2. Compare initial image obtained after 3D-sweep (A) with that obtained after applying VCI. (B) After using VCI tissular interfaces are more evident

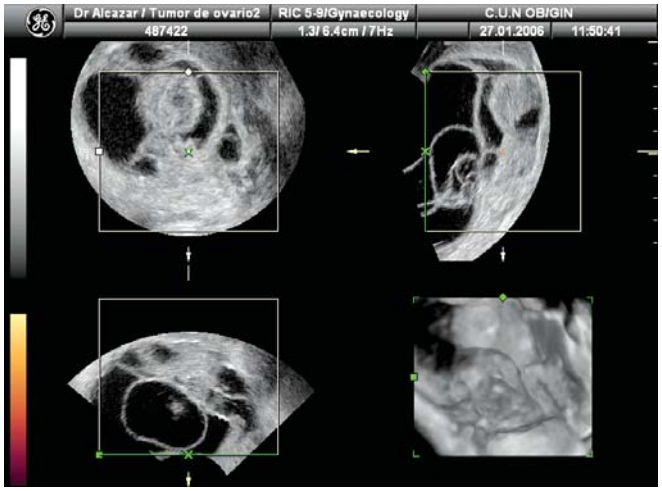


Fig. 5: Surface render imaging from the internal walls of a multiloculated solid cyst. Internal surfaces are clearer visible

Fig. 6: Surface render imaging from a submucous myoma after 3D sonohysterography

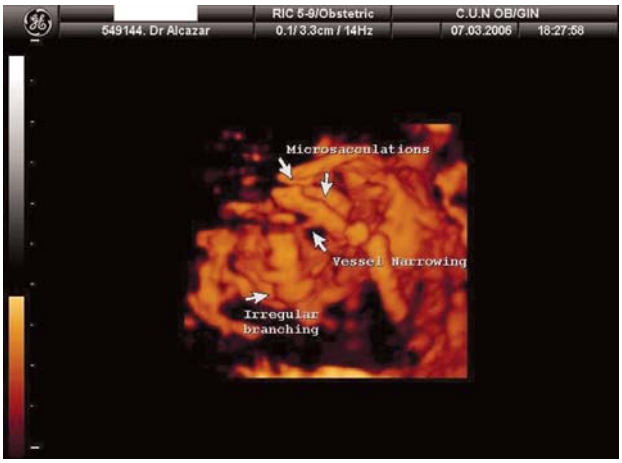


Fig. 7: Three-dimensional reconstruction of the vascular tree from a solid area of a cystic-solid adnexal mass. Some suspicious findings such as vessel narrowing, microsacculations and abnormal branching are clearly visible

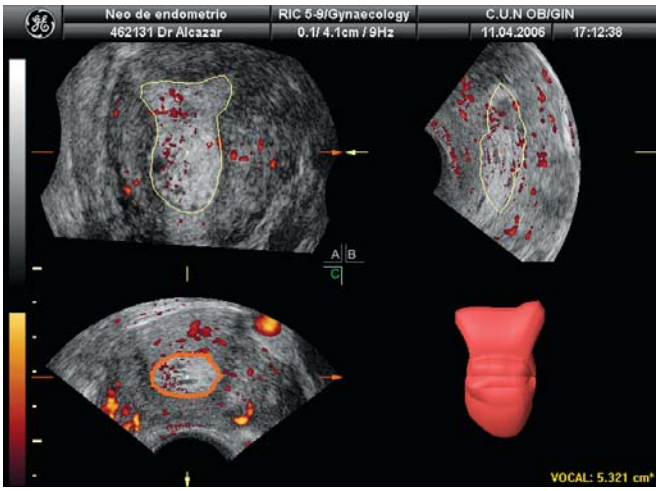


Fig. 8: Endometrial volume in a case of endometrial cancer obtained by the VOCAL method

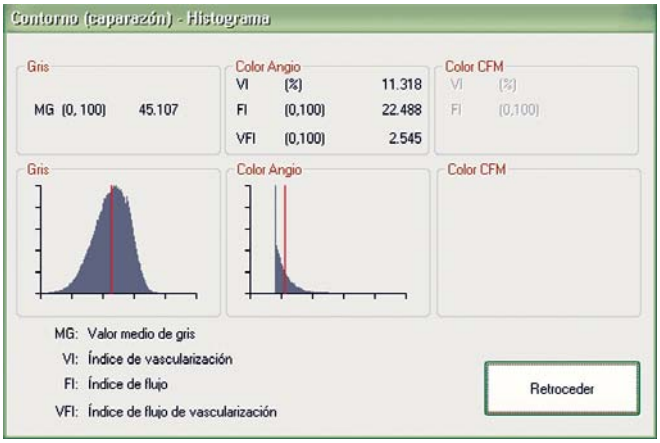


Fig. 9: After using the software "histogram" facility 3D power Doppler indices can be estimated

INVERSION MODE

Using the inversion mode the cystic areas within the volume are displayed in their entirety as an echogenic area, while the gray-scale portions of the image are rendered as transparent (Fig. 10).

This tool is thought to have some usefulness in gynecological patients, such as hydrosalpinx[34] or ovarian follicle counting.[35]

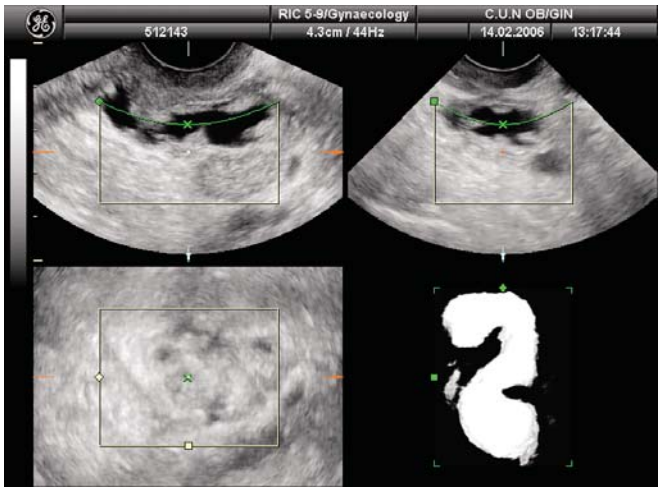


Fig. 10: Inversion mode used for depicting a hydrosalpinx. The cystic content within the dilated tube is depicted as solid and the shape clearly visible

AUTOMATED VOLUME CALCULATION (SONO-AVC)

This is the most recent advance in 3DUS. This tool allows an automated volume calculation of cystic areas, for example, follicle volume. It is thought to be a very promising tool in assessing the infertile woman and for predicting success of assisted reproductive technique.[36]

TECHNIQUE EFFICIENCY

Some recent reports have shown that 3DUS is a saving time technique and that improves efficiency of gynecological ultrasound.[37,38]

CONCLUSIONS

Three-dimensional sonography is the most recent major development in ultrasound imaging. It is progressively gaining acceptance in clinical practice. It will not replace conventional 2D ultrasound, but it is becoming more popular for its role in gynecology in certain specific clinical circumstances.

This new technique has become a useful research tool in many gynecological applications and its potential is likely to be further expanded in other areas in forthcoming years.

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