

Three-dimensional Ultrasound in the Fertility Clinic

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Abstract: The management of subfertility involves a detailed assessment of the couple to identify factors that may affect or predict the outcome of treatment. Three-dimensional imaging is one of the recent advances in the field of ultrasound which has several obvious benefits that relate to an improved spatial orientation and the demonstration of additional image planes such as the coronal plane. Many clinicians remain unconvinced by its reputed advantages and three-dimensional ultrasound is not without disadvantages. These mainly relate to the cost involved and training requirements. Three-dimensional ultrasound imaging is still at a relatively early stage in terms of its role as a day-to-day imaging modality in gynecology and reproductive medicine. Other than its application in the assessment and differentiation of uterine anomalies there is little evidence that three-dimensional ultrasound results in clinically-relevant benefit or negates the need for further investigation. Future work should ensure that three-dimensional ultrasound is compared to conventional imaging in randomized trials where the observer is blinded to the outcome such that its role in reproductive medicine can be truly evaluated in an evidence-based manner.

Keywords: Three-dimensional, ultrasound, ovarian reserve, reproductive medicine, gynecology, endometrial receptivity.

INTRODUCTION

The management of subfertility involves a detailed assessment of the couple to identify factors that may affect or predict the outcome of treatment and thereby allow an individualized, evidence-based approach to their care where possible. From a female perspective, ultrasound forms an important part of this assessment and is used to identify and exclude disease within the pelvis, monitor the response to treatment and, in conjunction with contrast, to assess the endometrial cavity and confirm tubal patency. It can also be used to predict the outcome of

subfertility treatment through qualitative and quantitative assessment of ovarian reserve and endometrial receptivity.

Two-dimensional (2D) ultrasound has an established role in this respect and is the standard against which all over imaging techniques must be compared. Advances in ultrasound have seen the development of Doppler and, more recently, three-dimensional (3D) ultrasound. However, these imaging modalities should be considered as adjuncts to conventional 2D ultrasound which is sufficient to allow a detailed assessment of most patients and a confident diagnosis in the majority. Three-dimensional ultrasound has certain theoretical and practical advantages, that make it an interesting tool and one that has attracted a great deal of attention of late. This review outlines and appraises these advantages and describes its potential clinical applications in the management of subfertile women.

The Principles of 3D Ultrasound

Conventional ultrasound allows the user to see a single image plane at any given time. The exact plane demonstrated depends upon the anatomical position of the object under scrutiny and the orientation of the transducer. Transvaginal 2D ultrasound of the pelvis, for example, generally provides views of the longitudinal and transverse planes of the uterus through which the ultrasonographer scrolls to develop their own three-dimensional image. The user is not able to see these independent planes at the same time and has to use the transducer in a dynamic fashion to assess the pelvic organs. This requires a certain degree of skill and inevitably involves some discomfort for the patient. Three-dimensional ultrasound, by contrast, involves less manipulation of the transducer which is held still once the central aspect of the object of interest is located and

whilst an automated acquisition of two-dimensional data is undertaken. The exact ‘volume’ acquired and the number of 2D planes within the acquisition can be varied according to the size of the object of interest and the degree of detail required. A slower acquisition speed, or ‘sweep’, results in more 2D scan planes being incorporated into the final volume acquired and is preferred unless the image naturally involves movement, such as blood flow or fetal movement, when a faster acquisition speed is required to avoid movement artefact. Acquisition speeds are inherently slower when additional 2D information is being obtained, such as when harmonic imaging or Doppler is applied, and the acquisition speed generally needs to be increased to account for this.

Once acquired, the 2D data can be reconstructed and demonstrated in a variety of ways, dependent on the nature of object being studied and the type of assessment required. All of the 3D display techniques rely upon production of a composite of multiple 2D images derived during the acquisition process. The 2D images have a specific relationship to each other and each pixel has its own Cartesian location that defines its relative ‘three-dimensional’ position within the dataset. A three-dimensional pixel is known as a volume element or ‘voxel’ and these are used to define volumetric data through computation of conventional 2D ultrasound data. These data can be rendered using various computer algorithms and viewed as a single three-dimensional object to provide an impression of depth and structure.

Whilst 3D rendered images are impressive three-dimensional data, they are typically displayed using the multiplanar view (Fig. 1). This shows the longitudinal (A) and transverse (B) planes, available with conventional 2D ultrasound but not normally demonstrable simultaneously, together with the

coronal (C) plane, a digital reconstruction of the plane orthogonal to the transducer (Fig. 1) not available with 2D ultrasound and specific to 3D imaging therefore. This additional information and the precise perpendicular relationship of these three planes to one another provide the user with more spatial information. This is best appreciated by manipulation of the dataset as the three planes are all mutually related such that movement within one plane produces geometrically equivalent movements in the other two planes. Any of these image planes can be examined in more detail by selecting a single plane and choosing to either enlarge the image or display it on its own or alongside multiple parallel slices of the same section by applying tomographic ultrasound imaging (TUI).

These various displays allow a virtual real-time, off-line assessment of ultrasound data that is not possible with conventional 2D ultrasound even when short cine-loops or longer video-recordings are used as these are dependent on the person who performed the scan and can only be observed and not physically manipulated to provide the reviewer with any additional information they may want. Three-dimensional ultrasound can, for example, be used to simply acquire 2D data that may be analysed in a two-dimensional manner. 3D represents a simplistic but excellent way to store 2D data therefore and this has important implications for data storage and training (Table 1). It can be seen that 3D ultrasound comprises of four basic steps; data acquisition, volume analysis and processing, image animation, and archiving of volumetric data.

Table 1: Advantages of three-dimensional ultrasound

<i>Advantage</i>	<i>Clinical use</i>
Data acquisition and storage	Off-line analysis of 2D data: <ul style="list-style-type: none"> • Allows a virtual real-time assessment of the patient in their absence • Educational opportunities and training • Telemedicine facilitates international collaboration and allows an immediate second opinion • Reduced scanning time and therefore exposure to ultrasound
Image displays	Multiple viewing options: <ul style="list-style-type: none"> • Choice as how to display and analyse 2D data • Standardization of examination procedures
The C plane	Additional information not available with 2D: <ul style="list-style-type: none"> • Improved spatial awareness • Demonstration of uterine anomalies and confirmation of normality • Diagnostic confidence
Three-dimensional data	Three-dimensional data analysis: <ul style="list-style-type: none"> • True volume measurements • Novel methods for the quantification of blood flow and vascularity • The potential for automated analyses which may improve work flow and prove cost-effective



Fig. 1: A three-dimensional multiplanar view of a normal uterus. The coronal plane clearly shows the uterine cavity has developed appropriately and that the fundus is not indented. The myometrium, which has a different echogenicity to the endometrial cavity, is normal and there is no evidence of fibroids or adenomyosis. The junctional zone can be seen surrounding the myometrial endometrial border

DIAGNOSTIC APPLICATIONS

One in four couples is affected by subfertility.¹ A detailed ultrasound assessment of the pelvis forms an essential part of the female investigation as it allows the exclusion of pathology, such as congenital uterine anomalies, uterine fibroids, polyps, ovarian cysts, and tubal disease and the prediction of treatment outcome.

Uterine Pathology

Congenital Uterine Anomalies

3D ultrasound has now become the gold standard investigation for uterine anomalies.² This is largely due to the multiplanar capability and high resolution of transvaginal 3D ultrasound, which provides precise anatomical information without the need for radiation, contrast material, or surgical intervention.³ The coronal plane of the image acquired using 3D ultrasound permits the simultaneous display of uterine fundus and serosal outline, that is difficult and generally not possible with conventional 2D ultrasound. The classification of uterine anomalies by 3D ultrasound using the coronal plane was first described by Jurkovic et al.⁵ Both arcuate uteri, which have a shallow depression in the fundal contour, and subseptate uteri, where the septum dividing the uterine cavity measures more than 10 mm in length, have a normal outer myometrial contour at the fundus as opposed to bicornuate, unicornuate, and didelphus uteri.

Comparing 3D ultrasound to hysterosalpingography and 2D ultrasound, Jurkovic et al concluded that whilst 3D ultrasound and hysterosalpingography, which was considered the gold standard tool for the investigation of uterine anomalies at the time, allowed the user to arrive at the same conclusion regarding the normality of the uterus, 2D ultrasound was less specific and resulted in more false positive findings.⁵ Raga et al and Wu et al both reported similar findings concluding that 3D ultrasound offered a 100% specificity for the exclusion of uterine anomalies and was able to differentiate between the different anomalies.^{6,7}

The diagnosis and differentiation of congenital uterine anomalies is clinically important as they are associated with an increased risk of abnormal pregnancy outcome⁸ which appears to improve with surgical correction of the anomaly.⁹ As many as 24% of women with recurrent pregnancy loss may have uterine anomalies¹⁰ which is approximately four times that seen in low-risk women where the prevalence is in the order of 5 to 6%.^{4,11} In terms of the type of anomaly, a similar distribution is seen between the different groups with arcuate uteri being the most common, followed by septate then bicornuate uteri with the more complex anomalies, such as uterus didelphus and single uterine horns, the least prevalent.¹² The type of anomaly is important as, in comparison to women with normal uterus, women with a septated uterus have a significantly higher proportion of first-trimester loss whilst women with an arcuate

uterus are more likely to suffer second-trimester losses and preterm labor.¹⁰

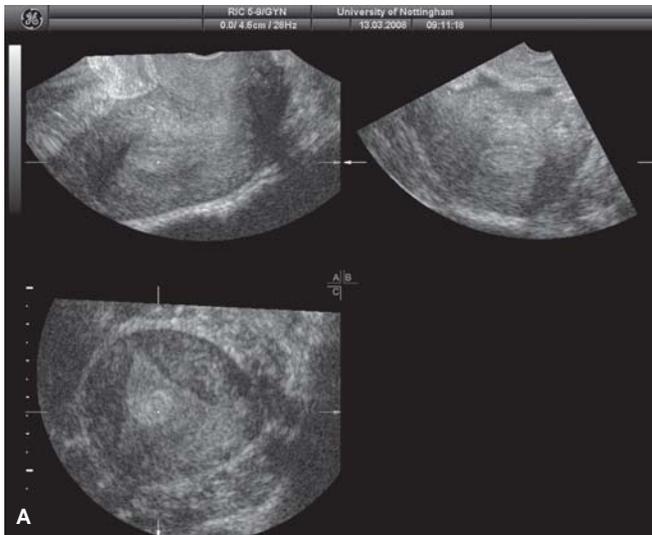
Endometrial Polyps

Endometrial polyps represent an excessive growth of endometrial cells that become space-occupying lesions within the uterine cavity. The evidence is unclear but polyps theoretically could affect implantation and are often removed if discovered prior to or during fertility treatment. Polyps are most readily identified in the late follicular phase of menstrual cycle, when the polyp can be seen to disrupt the endometrial triple pattern, or in the luteal phase when there is more contrast between the polyp and the endometrium which becomes increasingly homogenous due to the secretory changes that occur following ovulation.

Some studies suggest that 3D ultrasound improves the accuracy of diagnosis of endometrial polyps, with or without the instillation of saline, over conventional two-dimensional ultrasound. La Torre et al showed that 2D ultrasound had a specificity of 69%, 3D a specificity of 88%, and 3D sonohysterography a specificity of 100%¹³ in diagnosing endometrial polyps. However, Ayida et al who performed a similar study, found that two- and three-dimensional ultrasound were comparable when used in conjunction with saline sonohysterography.¹⁴ Studies have shown that the uterine cavity, endometrial lining, and myometrium are best visualized using sonohysterography¹⁵ and that these images are further improved by the use of three-dimensional ultrasound.^{16,17} 3D allows the images to be captured as the saline is introduced and these can then be reviewed after the procedure has been completed even if the saline leaks out quickly afterwards. One such study looked at 36 women with postmenopausal bleeding all of whom underwent three-dimensional sonohysterography.¹⁷ The results were compared against two-dimensional ultrasound alone, two-dimensional sonohysterography, and hysteroscopy with histological correlation. The results revealed that three-dimensional sonohysterography provided the most useful images of the uterine cavity and endometrial thickness and that these correlated well with the hysteroscopic findings. When available, 3D ultrasound with saline instillation has become the investigation of choice for endometrial polyps (Figs 2A and 2B).

Fibroids

Fibroids are benign tumors of the myometrial smooth muscle. They are defined as being intramural, subserosal or submucosal based on their position within the uterus and proximity to the endometrial cavity.¹⁸ Submucosal fibroids are generally considered to have detrimental effects on reproductive outcome but the most recent systematic review of the literature suggests that intramural fibroids also have negative effects on fertility and pregnancy outcome even when they do not affect the



Figs 2A and B: Endometrial polyp. (A) Demonstrates a classical 3D multiplanar view of the uterus with an endometrial polyp disrupting the triple layer pattern of the endometrium and also more visible due to contrast between the polyp and endometrium. (B) Demonstrates a 3D multiplanar view of uterus with saline infusion sonohysterography, allowing clarification on the presence, position, and size of the polyp

cavity.¹⁹ Accurate ultrasonographic identification is important therefore and should be used to classify the size, number and position of fibroids. Three-dimensional ultrasound has recently been used in this respect to map the exact location of fibroids in relation to the endometrial cavity and surrounding structures (Fig. 3). This is extremely important in triaging patients for open or hysteroscopic surgery, as the safety and effectiveness of the endoscopic approach is critically dependent on the exact position of the fibroid and the extent of its endometrial involvement. Sylvestre *et al* showed that three-dimensional imaging was associated with an improvement in the diagnostic performance of ultrasound in the diagnosis of intrauterine



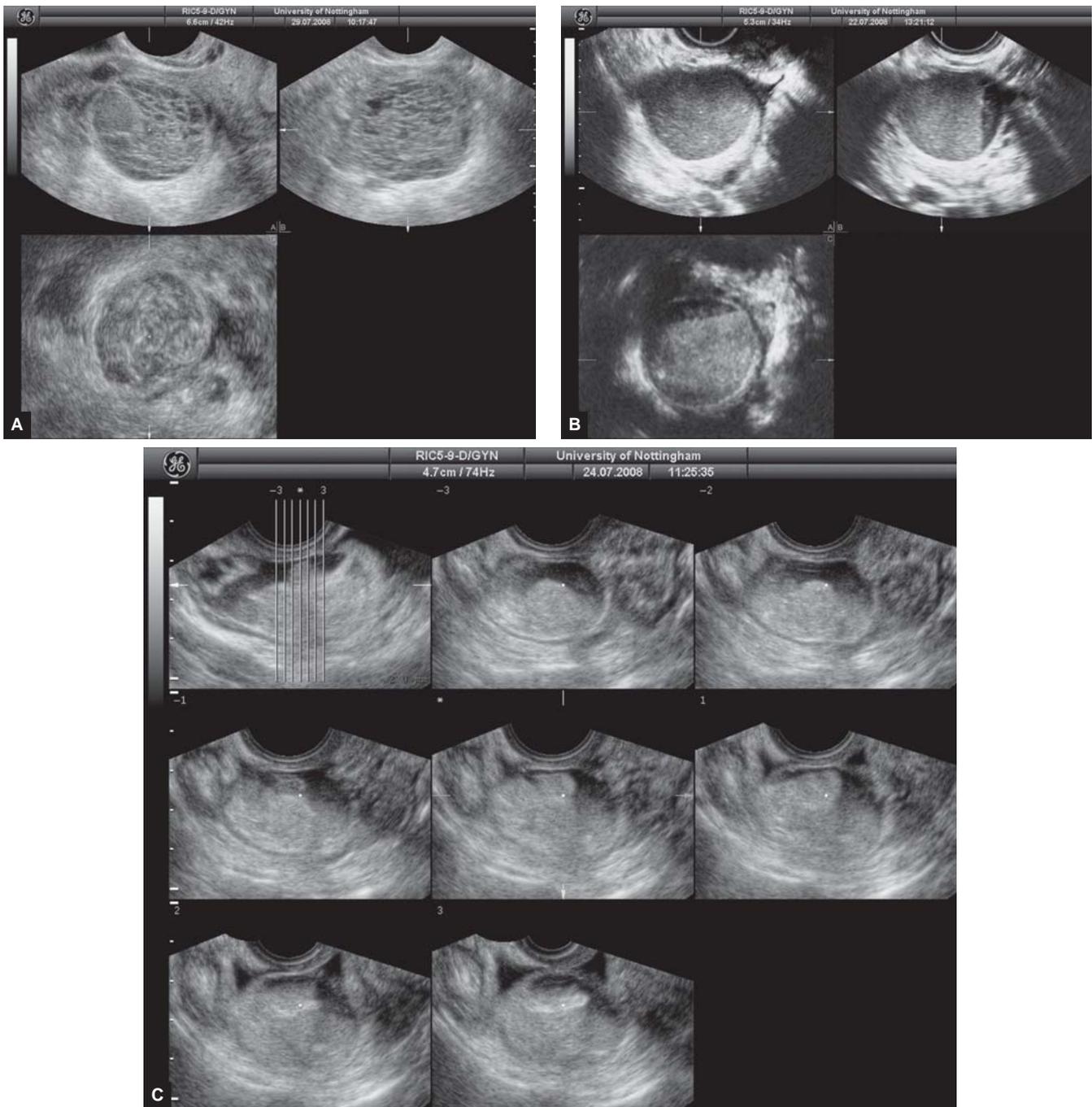
Fig. 3: Fibroid uterus. The figure is a 3D multiplanar view of uterus with a right posterolateral subserous fibroid. The coronal plane allows the precise location of the fibroid to be determined and also provides clarification on its relationship with the myometrium and endometrial cavity

fibroids reporting a sensitivity and specificity of 97% and 11% for 2D ultrasound compared to 87% and 45% for 3D ultrasound.²⁰ However, this study also revealed a sensitivity and specificity of 98% and 100% for 2D when used in conjunction with saline infusion sonography which clearly demonstrates how simple contrast media can increase the negative predictive value of ultrasound as 55% of patients were shown to have normal cavities following the infusion of saline.

Ovarian Pathology

Ovarian Cysts

Most ovarian cysts in women of reproductive age are benign in nature with characteristic ultrasonographic appearances.²⁹ Ovarian cysts are readily diagnosed with transvaginal ultrasound, which offers a sensitivity of 88-100% and specificity of 62-96% in the discrimination of benign and malignant adnexal masses.²¹ Many ultrasonographic misdiagnoses relate to the difficulty in differentiating between endometriotic, dermoid and hemorrhagic cysts.²² Hemorrhagic cysts have diffuse low-level echoes, reflective of the fibrinous strands and retracting clots they contain, and are readily recognisable through pattern recognition (Fig. 4A). An adnexal mass with diffuse low-level internal echoes ('ground glass' appearance) is highly likely to be an endometrioma especially if multilocularity and hyperechoic wall foci are also present¹⁴ but 8% of endometriomata demonstrate similar patterns to hemorrhagic cysts (Fig. 4B). In contrast, dermoid cysts demonstrate areas of focal acoustic impedance in association with bright echoes and hyperechoic lines and dots. A distinctive feature is the presence of a discrete highly echogenic focus with posterior shadowing (Rokitansky



Figs 4A to C: Ovarian cysts. (A) It is a 3D multiplanar view of the ovary containing a hemorrhagic cyst which has diffuse low level echos reflective of fibrinous strands and retractile blood clots. (B) It is a 3D multiplanar view of ovary containing an endometrioma which is classically described as a cyst containing echoes suggesting a 'ground glass' appearance. (C) It is a 3D tomographic ultrasound imaging of an ovary containing a dermoid cyst

protuberance). Other characteristics considered pathognomonic of a dermoid cyst include fine, echogenic bands representing hair within the cystic area and the presence of a fat-fluid level (Fig. 4C). Although three-dimensional techniques have the potential to improve the diagnostic accuracy of ultrasound for

differentiating between these benign ovarian cysts, through the additional spatial information provided by the multiplanar view, tomographic ultrasound imaging (TUI) and different rendering modalities, this needs to be tested in prospective studies.²²

Most benign ovarian cysts do not have a direct negative effect on a woman's fertility but their management may have implications especially in subfertile patients. The excision of an ovarian cyst measuring more than 5 cm, to reduce the risk of torsion and rupture, is common practice amongst many gynecologists.²³ Cystectomy, however, may have a detrimental effect on ovarian reserve as surgery necessitates division of the ovarian cortex and often involves electro diathermy to achieve hemostasis. The differentiation of benign and malignant cysts is important therefore and, in the absence of definitive evidence, surgery should not be routinely offered for benign cysts unless the patient is symptomatic.

POLYCYSTIC OVARIAN SYNDROME (PCOS)

PCOS is associated with reduced fertility due to disordered folliculogenesis and ovulatory dysfunction. It is also associated with an increased risk of ovarian hyperstimulation syndrome (OHSS) when controlled ovarian stimulation is used in conjunction with assisted reproductive treatments. A polycystic ovary is an ultrasonographic marker of the syndrome which also comprises clinical and biochemical parameters. The Rotterdam criteria used to define the polycystic ovary include the presence of twelve or more follicles measuring 2-9 mm and/ or an increased ovarian volume of more than 10 cm³^{24,25} (Fig. 5). Three-dimensional imaging can calculate ovarian volume more accurately and more reliably than measurements based on two-dimensional estimations.²⁶ It also facilitates a more precise follicle count and should, arguably, become the reference standard for ultrasound in the future although 3D has yet to become standard in all units or to be applied in units that have the facility for 3D imaging.

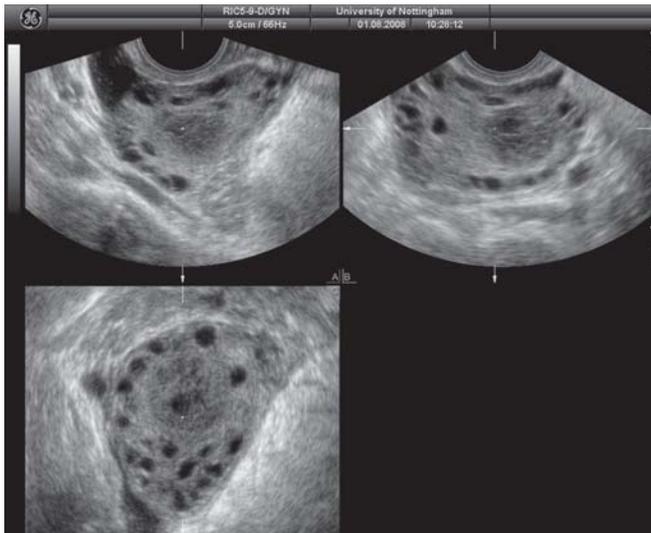


Fig. 5: A 3D multiplanar view of polycystic ovary. The figure is a 3D multiplanar view of an ovary with polycystic appearance as described in Rotterdam criteria, which includes the presence of twelve or more follicles measuring 2-9 mm and/or an ovarian volume of more than 10 cm³

Tubal Pathology

3D ultrasound aids in the diagnosis of adnexal disease by providing increased confidence in the differential diagnosis of ovarian and adnexal pathology as a result of the improved spatial awareness provided by the coronal plane and different viewing modalities, particularly TUI. The presence of blocked tubes or hydrosalpinges has implications for assisted reproductive treatments which are less successful.²⁷ Salpingectomy improves the outcome of IVF treatment and is currently recommended prior to instigating treatment.²⁸

Hystero-contrast-sonography (HyCoSy) is a simple procedure used to investigate the patency of Fallopian tubes. It involves the instillation of a positive contrast agent (Echovist) into the uterus that is readily identifiable on ultrasound as it contains multiple small air bubbles which render it highly hyperechogenic. The media can be seen to flow through the Fallopian tubes and spill from their ends if the tubes are patent and has a 75% concordance with laparoscopy and hydrotubation. HyCoSy allows avoidance of surgery and anesthesia associated with laparoscopy, and does not expose the patient to radiation unlike hysterosalpingography. It is recommended as the first line investigation for patients with no risk factors for tubal disease or clinical features of endometriosis. 3D HyCoSy may have certain advantages but the assessment requires the dynamic examination of contrast moving through the tubes and really necessitates 4D imaging which, until matrix transducers are available, does not have a fast enough frame rate.

PREDICTIVE APPLICATIONS

Assisted reproduction treatment (ART) refers to the more advanced therapies used to help couples conceive such as *in vitro* fertilization (IVF) treatment. There are two key areas where ultrasound can be used: to predict the woman's response to ovarian stimulation ('ovarian reserve') and to evaluate the chance of implantation of an embryo ('endometrial receptivity').

Ovarian Reserve

Ovarian reserve is a concept used in reproductive medicine and can be defined as the existent quantitative and qualitative supply of follicles which are found in the ovaries that can potentially develop into mature follicles which in effect determines a woman's reproductive potential (US National Institute of Health).²⁹ It is important to assess ovarian reserve accurately prior to commencing assisted reproduction treatment as it allows specialists to individualize patient treatment. Although there are no randomised controlled trials to show a definite benefit to treatment modification as a result of ovarian reserve screening the result allows the couple to be counselled appropriately and gives them a more specific idea of the chance of a poor or exaggerated response to ovarian stimulation. Ovarian reserve

can be quantified ultrasonographically or endocrinologically, along with age. Ovarian ageing is known to influence the ovarian response to stimulation, as measured by the oocyte yield at retrieval, and is characterized by the progressive depletion of the primordial follicular cohort.³⁰ There are essentially three ultrasound parameters used to assess ovarian reserve: (1) antral follicle count, (2) ovarian volume and (3) ovarian stromal blood flow. Of these markers, antral follicle count has emerged as a significant marker of ovarian reserve, predicting response to assisted reproduction treatment. Studies assessing antral follicle counts have been more encouraging than those assessing ovarian volume measurements, as they appear to demonstrate a more positive correlation with IVF outcomes. Transvaginal ultrasound can be used to assess the number of antral follicles measuring between 2-10 mm in diameter during the early follicular phase of the menstrual cycle. Antral Follicle count made using ultrasound is an ovarian reserve test and has been shown to be a reliable method of assessing ovarian reserve.³¹⁻³³ The antral follicle count is positively correlated with the primordial follicular population³⁴ and is a significant predictor of poor ovarian response. Haadsma et al evaluated antral follicles of different sizes and found a decline in the number of small antral follicles (2 to 6 mm) with increasing age, whereas the number of larger follicles remained constant. The total antral follicle count (tAFC) is made by counting the antral follicles ranging between 2 to 10 mm in both ovaries using either two-dimensional (2D) or three-dimensional (3D) ultrasound. 3D ultrasound allows off line assessment and also automated antral follicle counts to be made (Fig. 6), reducing scanning time and also more reliable measures than manual counts. Although the reproducibility of antral follicle count measurement is improved with three-dimensional ultrasound when compared to two-dimensional ultrasound,³¹ the prediction of ovarian response during assisted reproduction treatment is not enhanced with the use of three-dimensional techniques.³⁵ Ovarian volume can be calculated more reliably and accurately using three-dimensional ultrasound data.^{36,55} If the volume is less than 3 cm³ then a poor response is likely but if it is more than 10 cm³ the ovary can be considered polycystic and the patient is at an increased risk of ovarian hyperstimulation syndrome. Studies using three-dimensional ultrasound to investigate the relationship between ovarian volume and *in vitro* fertilization (IVF) outcomes have, however, generated different results and suggest volume may not be an important predictor.³⁷ A poor response to ovarian stimulation is likely if there are less than seven follicles in total³⁵ whereas ovarian hyperstimulation syndrome is more prevalent in women with more than twelve follicles in either ovary.³⁸

Pellicer et al were amongst the first to use three-dimensional ultrasound as an adjunct to conventional markers of ovarian reserve when they examined ovarian volume and the number of 'selectable follicles' measuring 2-5mm in a small group of low responders on day three of the menstrual cycle.³⁹ Both the

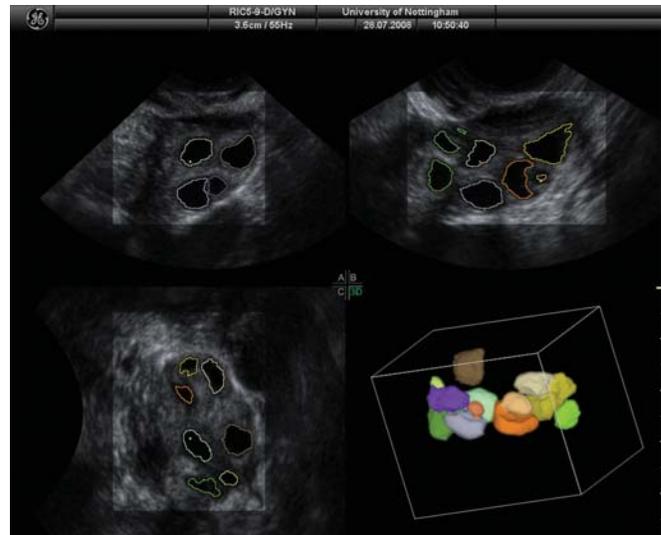


Fig. 6: Antral follicle. Count made using 3D multiplanar view and Sono automated volume calculation (SonoAVC). The figure demonstrates a 3D multiplanar view of an ovary along with a rendered image produced using SonoAVC which identifies each antral follicle and color codes the follicles

number of selectable follicles and the total number of antral follicles were significantly decreased in the 'low responder' group who also demonstrated significantly higher serum FSH levels despite having values within the normal range. Ovarian volume measurements, however, were similar between the two groups. Pohl et al also used three-dimensional ultrasound to quantify the number of follicles of varying diameter in 113 patients following 'down-regulation' but prior to ovarian stimulation.⁴⁰

Dumesic et al not only found early follicular phase antral follicle counts to be superior to ovarian volume measurements in predicting ovarian response to FSH but also that they were linked to androgen and insulin release.⁴¹ Both pre-treatment antral follicle count and serum androstenedione were positively correlated with subsequent total and mature oocyte number whilst FSH, LH, inhibin A and B, testosterone, dehydroepiandrosterone sulphate, oestradiol and total ovarian volume were unrelated to either in 25 'normal' ovulatory women. Insulin release in response to a standard oral glucose tolerance test (OGTT) was negatively correlated with total oocyte number but unrelated to mature oocyte number after controlling for antral follicle number. The antral follicle count, however, remained significantly correlated with mature oocyte number after controlling for post-OGTT insulin release again demonstrating its independent power of prediction.

The additional use of power Doppler does not appear to improve the prediction of ovarian response above that of antral follicle counts. Kupesic et al⁴² used quantitative three-dimensional power Doppler angiography to predict ovarian response in 56 women, with normal basal serum FSH levels,

undergoing their first cycle of IVF. They concluded that antral follicle counts were better predictors of ovarian response than ovarian volume and vascularity. A similar study by Ng *et al*³⁷ supported this conclusion.

Ficicioglu *et al* found that levels of AMH predict the number of oocytes with a positive predictive value of 96%.⁴³ This is also in agreement with other studies showing a strong correlation between AMH, antral follicle count and the number of oocytes retrieved.⁴⁴⁻⁴⁷

Endometrial Receptivity

Whilst successful implantation primarily depends on the quality and competence of the embryos transferred, the endometrial receptivity also has a pivotal role to play in implantation. An endometrium measuring less than 5 mm is unlikely to provide a healthy environmental bed for embryo implantation.⁴⁸ Studies by Schild *et al*⁴⁹ and Yaman *et al*⁵⁰ showed no significant differences between endometrial thickness/endometrial volume measurements in patients who conceived compared to those who did not, however did suggest a minimal volume of 2.0 to 2.5 cm³ was required for implantation to occur. This concept is supported by Raga *et al*.⁵¹ who assessed endometrial volume in seventy-two women on the day of embryo transfer and noted that no pregnancies occurred in patients with an endometrial volume below 1 cm³ and that implantation rates were significantly lower when the endometrial volume was less than 2cm³. It is uncertain if volume measurements provide more predictive information than standard two-dimensional measures of endometrial thickness as this has not been thoroughly assessed in randomised, blinded trials.

Kupesic *et al* studied 89 patients undergoing assisted reproduction treatment and noted significantly higher endometrial blood flow in women that conceived.⁵² Wu *et al* also found three-dimensional power Doppler angiography to be an important determinant of 'endometrial receptivity' on the day of hCG administration in 54 patients undergoing their first IVF cycle.⁵³ Three-dimensional ultrasound may also be used to examine endometrial vascularity and determine 'endometrial receptivity' prior to ovarian stimulation. Schild *et al* reported significantly lower indices of vascularity at down-regulation in 15 patients that subsequently conceived (20%) than in 60 non-conception cycles.⁵⁴ Endometrial measurements were once again not correlated with outcome. This may reflect a more profound pituitary suppression but is more likely to reflect patients responsiveness to exogenous hormonal therapy.

CONCLUSION

Three-dimensional ultrasound imaging has a significant role in certain areas of gynecology and reproductive medicine; however, its application as a day-to-day imaging modality in gynecology and reproductive medicine is yet to be explored.

Other than its application in the assessment and differentiation of uterine anomalies there is very little evidence that three-dimensional ultrasound results in clinically-relevant benefit or negates the need for further investigation. 3D does, however, have many theoretical advantages that should translate into clinical benefit if applied appropriately in a select group of patients who require a more detailed assessment than what conventional 2D ultrasound permits. Its role in assessment of ovarian reserve and prediction of outcome following assisted reproduction treatment is being researched extensively and the future studies will inform the speciality further. Future work should involve direct comparison between three-dimensional and conventional imaging in randomised trials where the observer is blinded to the outcome in order to evaluate its role in an evidence-based manner.

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