

Conventional versus 3D ultrasound for the investigation of infertile women

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Abstract

Background: With the technical development, ultrasound tends to overpass its limits and to become the main investigation tool even for situations when it was traditionally considered “second best”. It is more convenient both for patient and doctor, less expensive and has real diagnostic value.

Objective: The present paper, and its graphic back-up, are intended as a visual testimony of the fact that the newer three dimensional (3D) ultrasound technique is much more than a simple generator of “nice”, commercial, images. Moreover, its use may be extended from obstetrics to gynecological pathology, especially in cases related to infertility.

Materials and Methods: We performed a review of the main local infertility causes and their perception by the 3D ultrasound, as compared to the conventional methods. General literature citations were completed with personal cases and images. In our research, we used a Kretz – Voluson Expert 730 ultrasound machine with a full logistic equipment. Our database was completed over a period of 18 months and included various pathology, such as uterine anomalies, fibroids, polyps, ovarian cysts and many others.

Results: Three dimensional ultrasound represents the best tool in evaluating the uterine cavity, the endometrium, assessing its volume and vascularity pattern. It also offers a very good image of the uterine structure, the adnexal morphology and their relationship. It performs a thorough pelvic assessment by a single examination. Moreover, it may realize a hysterosalpingography, which is as efficient as the radiological method, but easier and with fewer side effects.

Conclusion: Even though it is technically more difficult and time consuming, a good practice and high quality ultrasound equipment offer a series of benefits over any other kind of investigation.

Key words: Female infertility, Three-dimensional ultrasound, Conventional ultrasound.

Introduction

Over the past decade there was a very important progress in digital technology, bringing along the

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development of the main diagnostic tool in most clinical fields, the ultrasound. With the increasing utility of the transvaginal ultrasound, the female pelvis became more and more accessible, a wider variety of gynecological pathology was open to diagnosis and treatment. Real time conventional scan and Doppler analysis are now part of the routine pelvic exam and an accurate evaluation allows gathering a number of anatomical and even

histological details, in search for functional information, such as luteal phase deficiency or the implantation prognosis. In this field, the 3D ultrasound seemed a natural step. Initially regarded as an experimental investigation tool, with few clinical utilities, it soon developed into a complementary method for obstetrics, where the liquid environment surrounding the fetus makes it possible to achieve images that are mainly spectacular and commercial. On the other hand, three and four dimensional ultrasound (3D/4D) examination of the fetus offers a general surface image, with functional information and even data about the internal organs, using the new technologies, such as STIC, minimum mode and reconstruction of the vascular structures. These technical acquisitions promoted 3D/4D ultrasound to a higher level, from a simple “gadget” for technicians, generator of “nice” images, to a useful diagnostic tool, with a very promising future.

Gynecological examination was initially doomed by the lack of a fluid environment. The first images obtained were at least disappointing. Only after the development of the new technologies and rendering modes, it became possible to acquire valuable diagnostic images of the female genital organs. The most important advantage was the visualization of the coronal plane.

It was a point of view completely new for pelvic examination, even though it is based on the well known fact that conventional ultrasound is a two-dimensional rendering mode of a three dimensional organ. Even with technical advances in gynecological 3D ultrasound, the coronal plane still remains the most important acquisition (1). The basis of the 3D examination in gynecology, derived straight from the surface rendering mode in obstetrics, consists in a progressive plane-by-plane two-dimensional scan, with digital image reconstruction. Starting from this point there are several possible rendering modes, which are employed according to the examiner’s purpose: enhance contrast or transsonic structures, visualize the coronal plane, or perform volume or vascularity calculations.

Materials and methods

In order to assess the benefit of 3D/4D ultrasound examination over different conventional methods, we used a Kretz – Voluson Expert ultrasound machine with full logistic equipment. Our selection of cases was completed over a period of 18 months, from October 2005, until March

2007. The purpose of this study was to achieve a wide variety of uterine and ovarian pathologies, documented with complementary diagnosis methods. We focused mainly on young women with local causes of infertility, as it represents a more and more important category, where prompt and accurate diagnosis is essential.

We considered the standard definition of infertility as failure to conceive after 12 months of unprotected regular intercourse. Statistically, it affects almost 10% of the couples, with 40% of the cases related to female pathology (2). Male infertility is involved in a similar percentage and in 20% of the situations, the etiologies are intricate. Traditionally, female infertility causes may be divided into cervical, uterine/endometrial, tubal and peritoneal infertility, and, finally, anovulation. All these territories will consist in targets for sonographic evaluation, conventional, as well as three dimensional. It is worth mentioning that over the past 20 years there has been a shift in the causes of infertility, passing from the ovarian and uterine anomalies, to tubal and male infertility factors. Mostly, this is due to the increasing frequency of tubal and pelvic surgery, ectopic pregnancies, use of intrauterine contraceptive devices, and, not to mention the more and more frequent pelvic inflammatory disease. Thus, there is a consequent increase in the number of couples which present with tubal infertility. Obstruction and damage of the fallopian tubes account for almost 35% of all infertility cases (3).

The study included a total number of 124 patients, aged between 25 and 38 years. Most of our patients had secondary infertility (86 cases – 69.3%), following by miscarriages (42 cases – 48.8%), terminations (16 cases – 18.6%) or deliveries (28 cases – 32.5%). Among them, we selected only those patients with uterine, tubal or ovarian anomalies, creating a study group of 92 women. Severe male infertility and chronic anovulation associated with endocrine anomalies represented exclusion criteria.

We performed a systematic review of the main local infertility causes, with comparison to similar data found in literature. Without aiming for an accurate statistics, we divided the cases according to the anomaly type. For presentation only the most representative cases for different local pathologies associated with infertility were selected. The paper, along with its graphics, is meant as a visual testimony of the fact the 3D/4D sonography represents a useful tool for the diagnosis and prognosis of uterine and ovarian pathology associated with infertility.

Results

I. Uterine pathology

I. Normal uterus is easily assessed using 3D ultrasound, where the coronal plane gives a good image of the endometrial cavity, the surrounding myometrium and of the uterine external contour, a fact of most importance. Conventional ultrasound, with a thorough scan in both sagittal and transverse

sections, offers an almost complete description of the uterus, endometrial thickness and vascularisation pattern. Three dimensional ultrasound does not substitute, but completes the examination by offering a complete image of the uterine cavity in one single acquisition, static rendering mode or VCI-C (figure 1), calculating the endometrial volume with VOCAL II, as well as vascularity indices (figure 2).

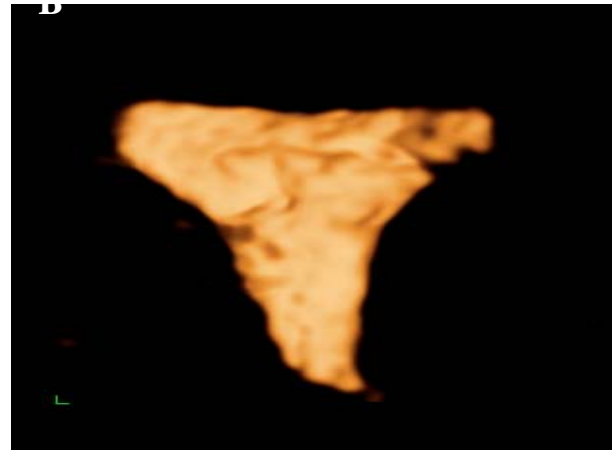
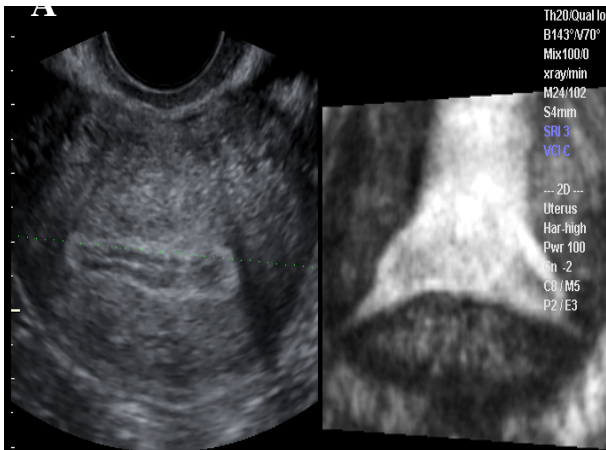


Figure 1. VCI-C rendering mode; image of the endometrial cavity in a transverse acquisition (A). The endometrial cavity – inversion mode during saline infusion. Offers the best data about the uterine cavity shape (B).

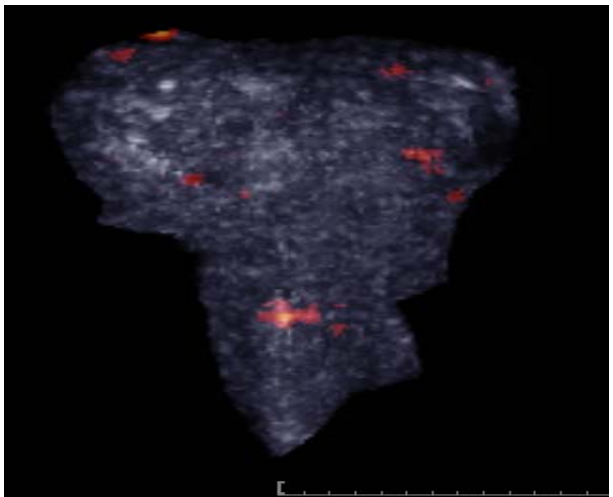


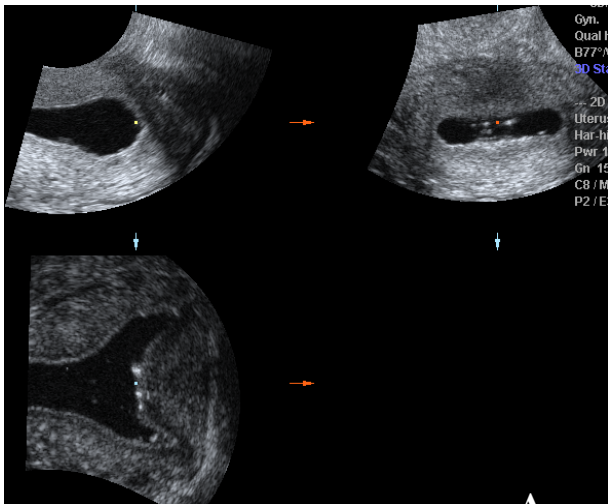
Figure 2. VOCAL II – digitally reconstructed image of the endometrium, including a periendometrial region (shell), useful for vascularity indices calculations

In some cases there is necessary to add to a simple sonography, like a saline infusion hystero-graphy (SIS), which is a very handy technique, cheap, with minimum patient discomfort, and very important diagnostic data. The endometrial cavity is easily visualized and the contrast is greatly enhanced, therefore it is helpful in differentiating between polyps and submucous myomas. It also facilitates the

Differential diagnosis between endometrial hyperplasia and carcinoma, along with the Doppler analysis (4).

It may visualize and, up to some point, treat uterine adhesions (5). Technically speaking, it is easy to perform, as a short outpatient procedure, does not require any kind of anesthesia, it is safe, avoids X-ray exposure, is well tolerated and performed at a minimal cost (10). The procedure is scheduled during the follicular phase, between

days 5 and 10. It requires a sonohysterography catheter, such as the Goldstein Catheter (Cook ObGy), or a pediatric no.8 Foley catheter, which has the advantage of a very low cost, but is more difficult to position, as the balloon should be inflated at the internal os and not in the uterine cavity. Under transvaginal continuous evaluation, small amounts of saline solution are being injected



in a pulsed manner. The sonographer gently slides the probe from one cornua to the other, then from the cervix to the fundus, reconstructing the uterine anatomy. 3D acquisition may be performed at any time, in a sagittal or transverse section (figure 3). The image may be modified according to necessities, using inversion mode, rotation and digital cutting.

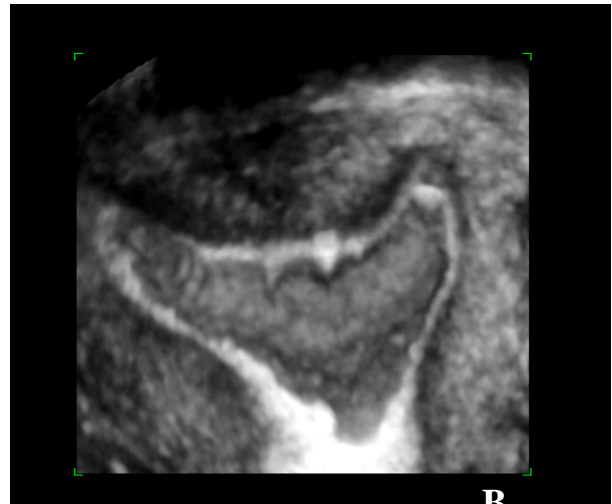


Figure 3. Sectional planes of the uterus during saline infusion (A); the most important is the reconstructed coronal plane. The same patient, a different rendering mode – VCI-C during saline infusion (B).

2. The endometrial polyp

Conventional ultrasound presents the endometrial polyp as a focal, unequal thickening of the endometrium, of higher echogenicity than the myometrium, with an easily detectable single feeding vessel. Large polyps may appear as diffuse endometrial thickening, being difficult to differentiate from simple hyperplasia. Three dimensional sonography may facilitate diagnosis, using static acquisition, direct or inversion mode during SIS (figure 4). The differential diagnosis from a submucous myoma in questionable cases is easily set. Also, the shape, the dimensions, the origin and the impact on the endometrial cavity are clearly visualized, guiding the therapeutic procedure. An alternative diagnostic method is hysteroscopy. With 100% reliability it has the advantage of offering a therapeutic solution in one step. But it is an invasive procedure, it requires a very skilled practitioner, it may be associated with complications as uterine perforation, infection, hemorrhage and it may require general anesthesia.

3. Uterine myoma

Most frequent tumors of the feminine genital tract, uterine myomas may be generators of infertility by obstructing the fallopian tubes, distorting the endometrial cavity and causing

subendometrial ischemia, thus interfering with gamete transport and implantation (6). Sonographically, they present as focal enlargements of the uterus, with a texture similar to the myometrium and posterior shadowing. The appearance greatly depends upon the presence of calcification or necrosis. Doppler ultrasound visualizes circular surface vessels, sometimes detecting the main feeding vessel. The resistance index is always relatively high, with an average of 0.55 (7). The exact position, the impact on the ostium tubae and the uterine cavity may be difficult to assess by conventional ultrasound. A very easy solution in many cases is offered by a static 3D acquisition or static VCI - C. The increased echogenicity of the endometrium improves the visualization of the uterine cavity contour, but sometimes, especially in large myomas located on the anterior wall, this may be extremely difficult. Instillation of saline enhances contrast and delineates the uterine myoma. Inversion mode and rotation of the image may offer exact data regarding the dimension, position of the tumor and degree of distortion of the cavity. In the same procedure it is possible to assess tubal patency, by direct view of the fluid spillage through the fallopian tubes under Doppler control, or indirectly, by the easy depletion of the uterine

cavity with fluid accumulation in the Douglas pouch. Three dimensional sonography with reconstruction of the volume creates a very good hystero-graphic image, without supplementary investigations. It guides the therapeutic procedure in cases deferred to hysteroscopic resection, by evaluating the degree of protrusion in the uterine cavity. In the same manner it, also, selects the cases to benefit from laparoscopic or classic myomectomy.

4. Mullerian anomalies

The exact incidence of congenital uterine anomalies is difficult to determine since many women with such anomalies are not diagnosed, especially if they are asymptomatic, but it seems to be around 2 to 4% of live births (8). The prevalence is higher among women with adverse reproductive outcomes.

As an example, the incidence of mullerian anomalies among women with recurrent first trimester miscarriage or late first trimester - second trimester miscarriage/ preterm delivery was 5 to 10 % and greater than 25% respectively, in another study (9). The most common type of mullerian anomalies are uterine anomalies, with a distribution as follows: septate/arcuate uteri (90 %), bicornuate uterus (5%), and didelphic uterus (5 %).

There is a special mention regarding the association with spontaneous first trimester abortions. Among all types of congenital uterine anomalies, the septate uterus presents the highest rate of miscarriage (10). Clinically, this is of greatest importance, as septate uterus is considered a "mild" anomaly and the differential diagnosis with bicornuate uterus, anomaly with a better fertility prognosis, is difficult.

An accurate diagnosis in all cases implies a very good visualization of the uterine cavity, with focus on the fundus, and a delineation of the uterine external contour. So far, the most commonly used diagnostic method was hysterosalpingography (HSG). It provides excellent view of the uterine cavity and cervical canal as well as, information related to tubal patency, but no data regarding the fundal shape. Moreover, it exposes the patient to ionizing radiation and requires an X-ray laboratory. Alternative method for external visualization of the uterus is laparoscopy, which is expensive, invasive, gives no information regarding the endometrial cavity. MRI may be employed in certain cases, with very good results, but at high costs.

Arcuate/septate uterus

The septate/arcuate uterus develops from a defect in canalization or resorption of the midline septum between the two müllerian ducts. The degree of septation varies from a small midline septum to total failure in resorption resulting in a septate uterus with longitudinal vaginal septum. Partial and complete uterine septa are defined by the proximity of the septum to the internal os; the presence or absence of a complete or partial vaginal septum is not relevant to the classification (11). A septate or arcuate uterus has a normal external surface, but two endometrial cavities, in contrast to a bicornuate uterus which has an indented fundus and two endometrial cavities. The distinction between arcuate and septate uterus is rather difficult and up to some point, subjective. It is accepted that the arcuate uterus has a slight midline septum with a broad, fundal basis and normal external surface, while the septate uterus presents a more important septum and sometimes may have a small indentation that does not exceed 10 mm depth. Sonographically, the two uterine cavities are seen as split endometrial echoes, best visualized during secretory phase. The degree of septation may be assessed by conventional scan or, much better, by three dimensional sonography, thick slice or VCI-C. The coronal plane offers a very good diagnostic image of the endometrial cavity, as well as the fundal contour. In unclear cases, saline infusion gives a perfect image of the uterine cavity. 3D acquisition with inversion mode creates a hystero-gram sometimes of better quality than the radiological image (figure 5).

In our study it was the most common mullerian anomaly, with a total of 18 patients, confirmed by HSG or laparoscopy. All sonographic images were diagnostic, and there were no false negative results. As a conclusion, apart from further pelvic evaluation, there is no need for more invasive testing.

Bicornuate uterus

A bicornuate uterus refers to a uterus in which the fundus is indented (arbitrarily defined as ≥ 1 cm) and the vagina is generally normal (12). This anomaly results from only partial fusion of the müllerian ducts. This leads to a variable degree of separation of the uterine horns that can be complete or partial. Characteristically, there is only one cervix. Thus, the diagnosis depends on the very good visualization of the two endometrial cavities and the cervix. From a theoretical point of view, it is easy to obtain a good coronal plane, but,

sometimes, it may turn out to be quite difficult, due to some degree of uterine rotation. In our study group, we had 3 patients with bicornuate uterus. We had a sonographic diagnosis in two cases. The third one was diagnosed as a septate uterus, rectified after the HSG. Saline infusion remains a very good method of clearing up a diagnosis, when necessary.

Didelphic uterus

Uterine didelphys, or double uterus, occurs when the two müllerian ducts fail to fuse, thus producing duplication of the reproductive. Generally the duplication is limited to the uterus

and cervix [uterine didelphys and bicollis (two cervixes)] although duplication of the vulva, bladder, urethra, vagina, and anus may also occur. A complete vaginal septum, generating an obstructed hemivagina, may be associated with ipsilateral renal agenesis (13).

Women with a didelphic uterus and bicollis often have good reproductive outcomes. A septated vagina occurs in 75 % of cases and may cause difficulty with sexual intercourse or vaginal delivery (14).

We encountered the anomaly in two of our patients, in one case associated with incipient pregnancy (figure 6). A correct diagnosis was stated in both cases using 3D ultrasound, with the remark that sonography cannot evaluate vaginal septum.

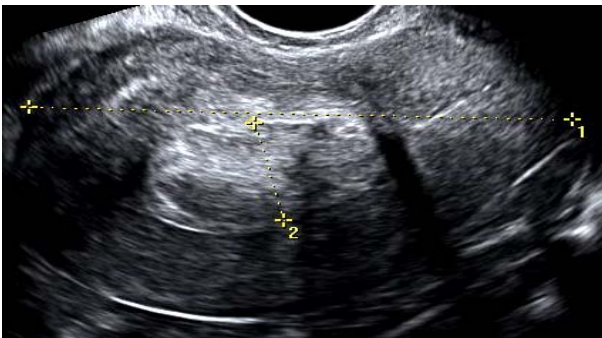


Figure 4. Large endometrial polyp – conventional transvaginal sagittal scan (A) and 3D image in the coronal plane (B).

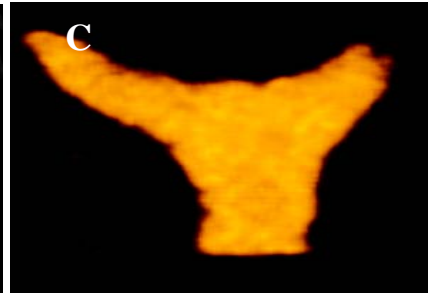
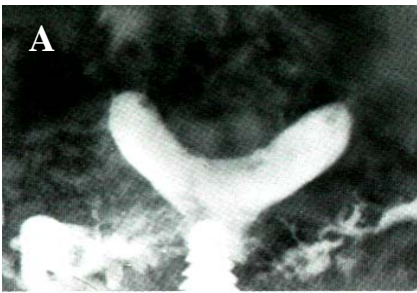


Figure 5. Comparative images of the arcuate uterus: A – radiological HSG; B – VCI-C acquisition in the coronal plane; C – inversion mode during SIS.

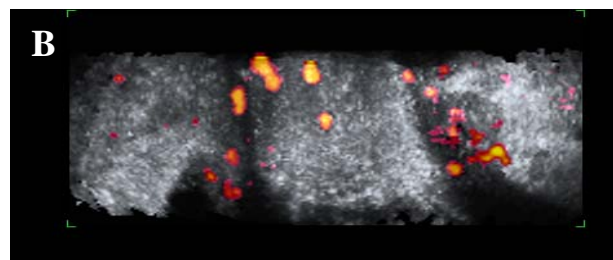


Figure 6. Didelphic uterus with incipient pregnancy in one hemiuterus; comparative image of the static acquisition (A) and “glass body” (B).

II. The ovaries

Sonographic evaluation of the ovaries is directed towards their number, size, location, presence of dominant follicle; correlates follicle size to endometrial appearance and measurements; evaluates the cul-de-sac; assesses the corpus luteum, as a very important prediction factor for early pregnancy outcome; notes the presence of persistent follicular cysts. The ovarian volume is age dependent, as well as the follicular size and number and the degree of stromal vascularity. All these parameters may be easily assessed by 3D sonography, using the VOCAL II program. Their importance increased during the last decade, replacing the older hormonal parameter, such as the estradiol (E2) level, as predictor of follicular development and maturity.

The follicular size may be expressed as a two-dimensional data, varying from 16–18 mm (gonadotropin stimulation) to 20–24 mm (clomiphene citrate stimulation), or as a volume of 3 to 7 mL. The stromal vascularisation indices are calculated using the VOCAL II program after the follicular volume is taken out from the total ovarian volume. Resistance to ovarian artery blood flow begins to decline in the dominant ovary during the phase of rapid follicular growth, in association with rising serum estradiol concentrations, and reaches a nadir at the time of ovulation. Thereafter, it does not change for four to five days, and then gradually increases to a level slightly lower than that in the early follicular phase. This represents an important monitoring tool for stimulated cycles.

The most important ovarian event of luteal phase is represented by the development of the corpus luteum. Traditionally, a cystic structure of variable size, but less than 4 cm, it can actually have many forms and the definitive element is the rich peripheral vascularisation, described as a “fire ring”. Sonographically, the corpus luteum is easily accessible. For a long time it was believed that progesterone levels were correlated with size and appearance of the corpus luteum, that is the proportion of the fluid component. Later it was proved that luteal function is related to the degree of thecal vascularisation, characterized by a very low resistivity index (RI), which returns to normal 7 to 10 days after the ovulation in the absence of fecundation.

Abnormal vascularisation, with increased RI in the dominant ovary is a marker of luteal phase defect and a poor pregnancy outcome (15). The solitary ovarian cyst benefits of a correct volume calculation using 3D ultrasound and a graphic

representation of the structure, its shape and relations. A cyst offers a fluid environment, facilitating the view of inner structures, such as intracystic papillae or vegetations, clearing the etiology and the prognosis (figure 7). It interferes with fertility whenever a great proportion of ovarian substance is destroyed, but it represents one of the most frequent sonographic findings. The VOCAL II associated with Doppler acquisition offers information about peripheral vascularisation, as a supplementary prognosis index.

III. The fallopian tubes

Evaluating the tubal patency represents a key step in the assessment of the infertile couple, especially in situations with risk factors for tubal damage.

Over the past 20 years there has been a shift in the causes of infertility, passing from the ovarian and uterine anomalies, to tubal and male infertility factors. Obstruction and damage of the fallopian tubes are accounting for almost 35% of all infertility cases (16). Normally, the fallopian tubes are not accessible to ultrasound evaluation, unless their diameter is increased by a pathological process, such as hydrosalpinx, pyosalpinx, ectopic pregnancy, tubal carcinoma or torsion. The diagnosis of tubal patency has changed very little during time, laparoscopy with chromo per tubation being still considered the “gold standard”, as it was 20 years ago, along with radiological HSG. Even though it is not possible in all situations we consider that 3D ultrasound may represent a very good diagnostic tool, in cases with dilated tubes and a good image of the female pelvis. The most representative rendering mode is inversion mode, very spectacular and easy to handle, especially in patients with an amount of fluid in Douglas pouch. A special remark has to be made regarding the evaluation of tubal patency in patients with non-dilated salpingae. Even though very little related to 3D ultrasound, saline infusion hysterosalpingography may benefit from its techniques.

A variable amount of saline solution is injected in pulses, under continuous vaginal scan. Power Doppler permits a good image of the tubal passage (figure 8) and it may be combined with 3D acquisition, creating a graphic representation of the fallopian tube. In some cases during the saline passage the tube is dilated such as a static acquisition with inversion mode is possible, but this is rather accidental, as it requires a long saline pulse and an important tubal diameter.

With all its disadvantages, such as case-to-case variability, time consuming technique, and high

rate of false positive results, the ultrasound evaluation of the fallopian tubes still represents the

main developing direction for future tubal investigation.

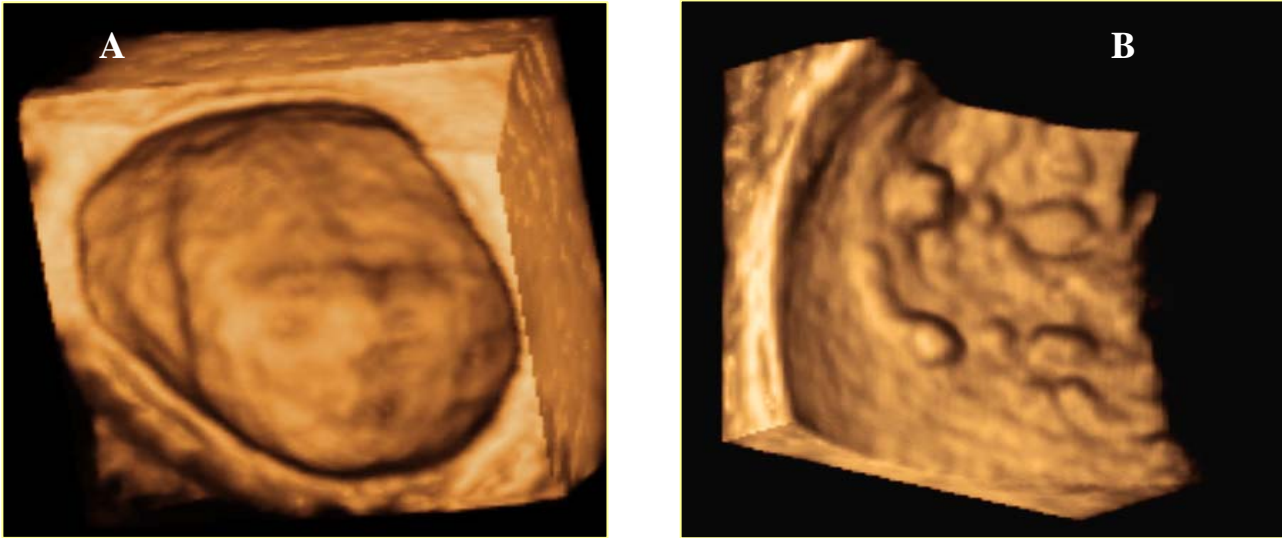


Figure 7. Rendering of the inner surface of a serous cyst (A). The fluid content allows easy visualization of intrapapillary projections

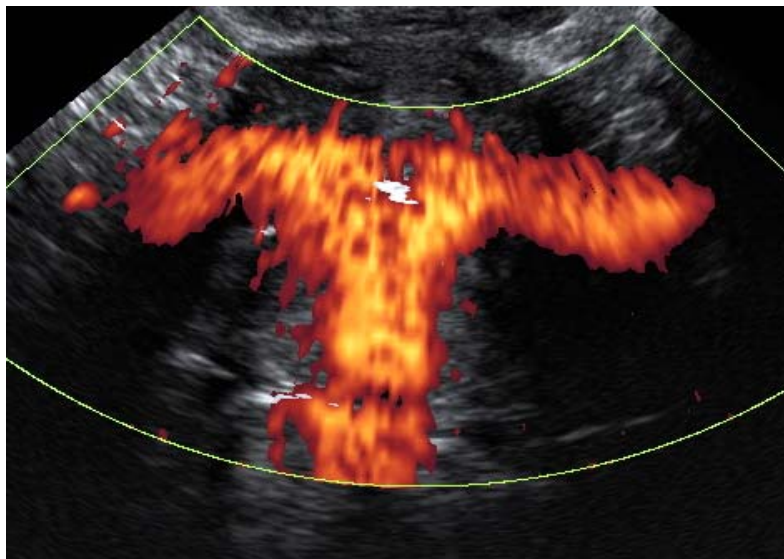


Figure 8. Saline infusion hysterosalpingography under power Doppler control shows easy passage of the fluid through both fallopian tubes

Discussion

Even though sonography seems to be the handiest diagnostic method, easily employed in out-patient clinics, when an accurate diagnostic is needed, especially in patients with minimal pathology, it implies a lot of medical energy and time. The first condition for a good image is a very preferment ultrasound machine. Secondly, training and experience bring along more and more diagnostic details. It is difficult to talk about a learning curve, as acquisition and investigational techniques differ greatly from one case to another,

and from one type of pathology to another. Definitely, a large experience with conventional ultrasound in female pelvis pathology is required, as well as a good acquaintance with 3D/4D technology.

As in the obstetrics field, further technical development is expected to bring along easier and more comfortable ultrasound diagnostic methods. Until then, we can still conclude that sonography, in the hands of a skilled practitioner, with a good technological basis, is one of the best diagnostic tools in gynecology, successfully replacing more invasive methods.

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