Imaging techniques for assessment of tubal status

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ABSTRACT

Fallopian tubes make a vital portal for transfer of gametes and embryo. Tubal factor is responsible for infertility in 25-35% of cases. Hysterosalpingography (HSG) has been used to evaluate the uterine cavity and the tubal status since decades. It uses iodinated contrast and X-rays and is painful and inconvenient for patient. Laparoscopy is considered to be the gold standard for tubal evaluation, but is an operative procedure and needs anesthesia. Though ultrasound is a modality of choice for assessment of uterus and ovaries, it does not allow assessment of the fallopian tube unless there is any fluid surrounding it or inside the lumen. This fluid interface can be created artificially by introducing saline in the uterine cavity and fallopian tubes and scanning simultaneously. The procedure is named Saline infusion HSG. Saline infusion sonohysterosalpingography (SIS) can be done with B mode US and Doppler. SIS can demonstrate a patent tube but if blocked, the site of block cannot be demonstrated. Ultrasound contrast agents can be used for tubal assessment using contrast mode on the scanners. This procedure is known as hystero-contrast sonography (HyCoSy). This actually shows the passage of hyperechoic contrast agent through tubal lumen and delineates it and locates the site of block. Using the volume ultrasound may even make the demonstration of tubal status and fimbriae better. Results of HyCoSy have been found to correlate well with laparoscopic findings, which are a gold standard. It is recommended by National Institute for Health and Clinical Excellence as a primary investigation for tubal assessment in patients without any positive history of tubal damage and also can replace a second look laparoscopy.

KEY WORDS: Hystero-contrast sonosalpingography, saline infusion salpingography, tubal assessment

INTRODUCTION

Tubal pathology is a cause of subfertility in 25-35% of subfertile couples. Evaluation of fallopian tubes therefore forms an essential part of evaluation of a subfertile female. Several investigations have been used since decades to evaluate the tubal patency.

It has been established that when the follicle grows to maturity in the ovary and luteinizing hormone surge leads to follicle rupture for release of the ovum, the fimbrial end of the tube proceeds to cover the ovulation site. The fimbrial processes cover the ovary like a ball being held in the palm.[1] The ciliary movement in the tubal lumen leads to development of negative pressure that sucks the ovum from the follicle into the tubal lumen. The ovum then advances in the tubal lumen, where the sperms have reached already after a natural intercourse or intrauterine insemination. Fertilization occurs in the tube and the embryo advances toward uterine cavity for implantation. Fallopian tubes are not just tubular portals, but are motile structures and have peristalsis. This explains that the tubo-ovarian relationship and tubal function in the form of tubal peristalsis and fimbrial function are as important as patency of the fallopian tubes for preservation of fertility.

INVESTIGATIONS FOR ASSESSMENT OF TUBAL STATUS

Various non-surgical and surgical investi gative modalities have been reported to assess fallopian tubes. An ideal test should correctly identify all women with tubal disease with minimal false negative test results. Further, the tests should be cost-effective, well tolerated by the patient and should not have any complications. However

such an ideal investigation is yet to be found. Therefore, various tests have been tried to assess the tubal status. While non-surgical techniques such as hysterosalpingography (HSG) (Carey 1914) and ultrasound based techniques like saline infusion sonography (SIS) (Corfman and Taylor 1966) and hystero-contrast sonosalpingography (HyCoSy) (Deichert 1993) are less invasive and associated with less serious risks than surgical technique such as laparoscopy and dye test (Chromopertubation). Though, the latter is considered the gold standard for assessment of tubal patency and pathology.

HYSTEROSALPINGOGRAPHY

HSG is widely used for tubal evaluation in subfertile women. This method is fairly accurate in detecting proximal tubal disease, is safe, not much expensive and may potentially be associated with increased pregnancy rates.[2] HSG provides optimal delineation of the fallopian tubes, allowing detection of tubal patency, tubal occlusion, tubal irregularity and peritubal disease. In general, HSG is done in the proliferative phase of the cycle in order to ensure that woman is not pregnant when the procedure is performed. However HSG should not be done in patients having any co-morbidities such as pelvic inflammatory disease, previous ectopic pregnancies or endometriosis.

MATERIALS AND METHODS

An analgesic or antispasmodic agent is given to the patient, about 1 h prior to the procedure to reduce lower abdominal discomfort and to avoid tubal spasm. Testing for chlamydia and/or prophylactic antibiotic is recommended to reduce the risk of pelvic infection. Patient is placed in lithotomy position and aseptic precaution is essential. Speculum is used to expose the cervix. Vagina and cervix are cleaned with antiseptic solution. Anterior cervical lip is grasped with tenaculum, HSG canula is introduced and stabilized into the cervix. Radio-opaque contrast solution is introduced through the HSG canula into uterus. Solution is warmed to body temperature and very small amount is introduced. Under fluoroscopic guidance, filling of the uterine cavity and passage of the radio-opaque solution into the tubes and its spill from fimbrial end is observed and documented in the form of X-rays [Figure 1].

HSG allows to study the endometrial cavity and diagnose mullerian abnormalities and endometrial lesions [Figure 2], in addition to its main use to assess the whole tube, condition of the tubal lumen and site of block [Figure 3]. Moreover, the radioopaque contrast used for the procedure, contains iodine and therefore has a risk of causing a reaction. The procedure is to be done in the radiology set up where both the gynecologist and the patient do not feel very comfortable.

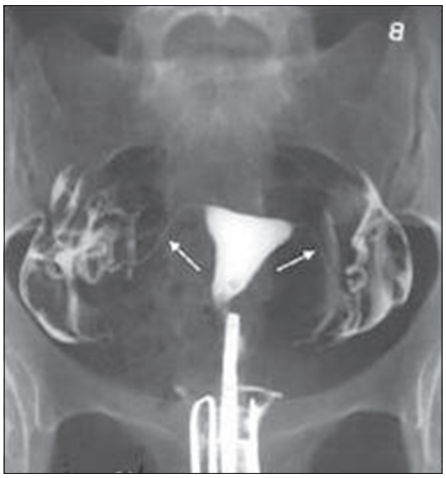

Figure 1: Normal hysterosalpingography

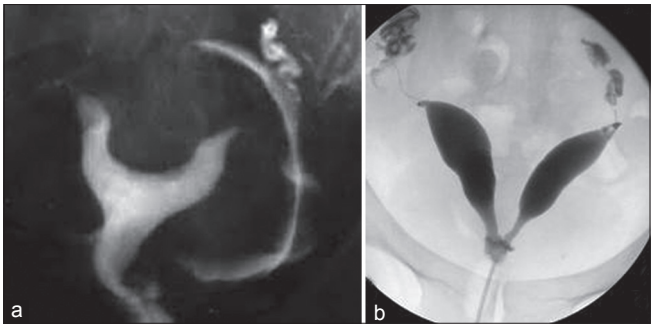

Figure 2: (a and b) Hysterosalpingography showing duplication abnormalities of uterus

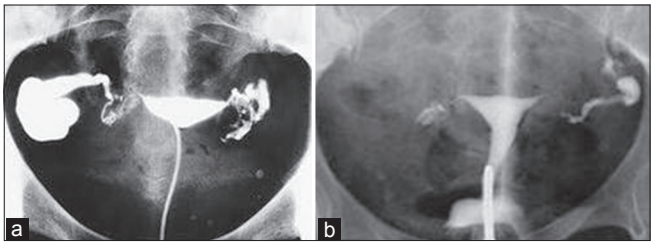

Figure 3: Hysterosalpingography showing (a) right hydrosalpinx, (b) right tubal block

However, the main disadvantages are exposure to radiation and its high false negative rates.

Though HSG has been used for several years for tubal assessment it has been shown in meta-analysis based on these three studies gave pooled estimates of sensitivity and specificity for HSG as a test for tubal obstruction of 0.65 (95% confidence interval [CI]: 0.50-0.78) and 0.83 (95% CI: 0.77-0.88), respectively. Tubal block seen on HSG will be confirmed by laparoscopy in only 38% of the women.[3] When HSG suggests that the tubes are patent, this will be confirmed at laparoscopy in 94% of the women and thus, HSG is a reliable indicator of tubal patency. These findings imply that after abnormal HSG, even in cases of bilateral pathology such as obstruction, it is

still worth performing laparoscopy because, in a considerable number of these patients, the laparoscopic diagnosis allows IUI treatment to remain an option.[4]

Use of ultrasound to test tubal patency may potentially avoid the risk of radiation, while providing the necessary information as provided by HSG. Moreover, ultrasound is an investigation of choice for assessment of uterus and ovaries and was therefore tried for the assessment of the fallopian tubes also.

SONO HYSTERO SALPINGOGRAPHY

While transvaginal ultrasound has now proved its place for assessment of uterus and ovaries, normal fallopian tubes are impossible to visualize on ultrasound without any intervention. This is so because there is no tissue-fluid interface when the tubes are normal. Fallopian tubes can be identified only when there is fluid in the tubal lumen or outside the tubes. This means that tubes can be identified on ultrasound when either there is hydrosalpinx or free fluid in pelvis [Figure 4a and b] or fluid is introduced in the tubal lumen or in the pelvis. Fluid can be introduced using a catheter through cervix to visualize and assess the fallopian tubes by ultrasound.

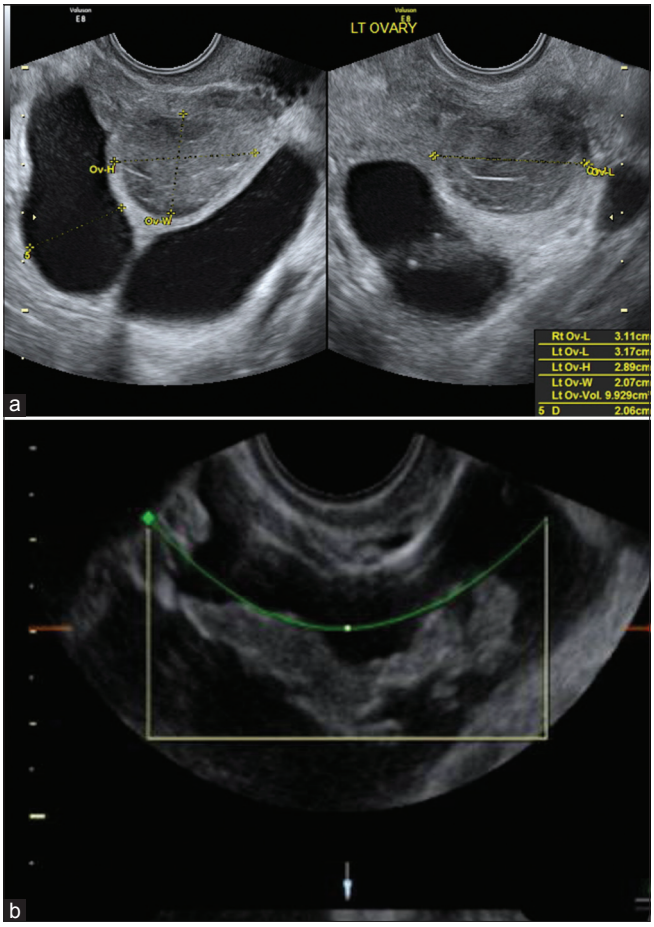

Figure 4: Fallopian tube on ultrasound identified because of (a) Fluid in the tube. (b) Fluid outside the tube – in pelvis

Sonographic evaluation of tubes was initially described by various authors, Nannini *et al*.,[5] Richman *et al*.[6] and Randolph *et al*.,[7] who performed abdominal sonography following intracervical injection of fluid, but was reported first by Richman. For this procedure, 200 ml of saline was introduced transvaginally, through the cervix into the uterus. Fluid would fill up the uterine cavity and pass through the tubes into the pelvic cavity. Retrouterine fluid seen on abdominal ultrasound was accepted as a criterion for patency. Tüfekçi *et al*. in their study also reported use of isotonic saline, but with transvaginal ultrasound for tubal patency in 1992.[8] Deichert *et al*. was the first to report on transvaginal sonographic evaluation of tubal patency, following transcervical injection of echogenic ultrasonic contrast fluid.[9] This investigation was given different names by various workers: SIS, saline sonosalpingography, saline HyCoSy, etc.

TECHNIQUE

Sonosalpingography is ideally done in mid proliferative phase (day 6-10 of a typical 28 day cycle), after menstruation stops but before ovulation occurs, to reduce the risk of disturbing an early pregnancy. Oral analgesic, ibuprofen 400-600 mg may be given 1-2 h before the procedure. Pre-procedural screening for infections like chalmydia and/or prophylactic oral antibiotics are recommended. Strict asepsis is essential. A detailed transvaginal ultrasound scan is done to assess the position of pelvic organs and to rule out any pathologies, which would come in the way of the procedure. Moreover, any free fluid in pelvis is also checked for.

The probe is removed and speculum is placed in the vagina to visualize the cervix. Vagina and cervix are cleaned with antiseptic solution. If required, cervix is fixed with tenaculum and manipulated to align it with uterus. A 6F-8F balloon catheter or a canula specially devised for SIS or HSG, is attached to a 10 ml syringe prefilled with saline. The catheter is introduced through cervix into the uterus. Balloon is distended with 1-2 ml of distilled water or normal saline and is placed just beyond the internal os. Alternatives to this catheter are pediatric feeding tubes or small gauge Foley's catheter. Once the catheter is fixed, tenaculum and speculum are removed and transvaginal probe is introduced into the vagina for further assessment.

Saline is injected through the catheter slowly. Scanning is done to assess the uterine cavity that is distended by saline and also passage of saline (fluid) seen through the tubes. When uterine cavity is filled with saline,

any endometrial pathologies can be demonstrated and diagnosed [Figure 5]. Spill of saline from fimbrial end is seen as fluid flow surrounding the ovary and its collection in pelvis on B-mode scanning [Figure 6]. Absence of spill may indicate blockage. It is not always possible to document the spill from the fimbrial end of individual tube. In such cases fluid accumulation in pouch if douglas confirms patency of at least one fallopian tube. In patients with bilateral block, distension of the uterine cavity causes severe pain and no spill is observed. Once the procedure is completed, the instruments are removed. Patient is informed that she might get some pelvic cramping or spotting, but the symptoms are short termed and should not worry about it. The accuracy of SIS compared to chromopertubation varies from 81.82%[10] to 100% respectively.[11-13]

The procedure is has no major complication except nausea, vomiting and mild to moderate pain. The risk of pelvic infection and associated peritonitis is approximately 1%. Vasovagal syncope is rare during or after the procedure. The reported prevalence of complications combined is 8.8%.[14] Failure to perform or complete the procedure was documented in 7% in a meta-analysis of 24 studies and 2278 procedures.[15]

RELIABILITY OF THE PROCEDURE

The agreement of transvaginal salpingosonography compared with X-ray HSG was 94%, the sensitivity 50%, the specificity 97%, the positive predictive value (PPV) 50% and the negative predictive value (NPV) 97%.[16]

Results of SSG correlated positively with laparoscopy in 97% and SSG and HSG showed 93% correlation.[17]

Another study showed sensitivity of SSG as 97.3% for open tubes with specificity of 92% whereas sensitivity of laparoscopy was 94.6% and sensitivity of HSG was 94.5% but with a specificity of only 84%.[18]

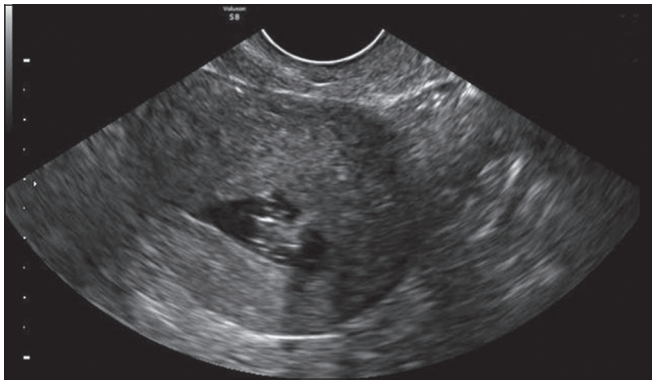

Figure 5: Sonohysterography on b mode

SIS HyCoSy is accurate in determining tubal patency and evaluating the uterine cavity and can supplant HSG as the first-line diagnostic test in an infertility work-up.[19]

The shortcoming of the procedure is that even when patency of individual tube can be confirmed, it does not give any information about the site of the block, condition of the lumen and tubo-ovarian relationship. Some variations in this technique were tried to overcome this shortcoming.

MODIFICATIONS

Several modifications have been made to this basic procedure of SIS to improve its diagnostic accuracy as an investigative modality for tubal assessment. The reported modifications are:

- Using pulse Doppler
- Using color Doppler
- Combining air and saline
- Three-dimensional (3D) saline sonosalpingography.

Using pulse Doppler

If examination during B mode reveals evidence suggesting tubal occlusion or if a small segment of the tube is not visualized, a pulse Doppler examination can be performed.[20] Doppler gate is placed where the block is expected. This is exactly the point beyond which the tube is not filled with saline or color flow is not seen on injection of saline when examination is done with color Doppler. The gate is reduced to the width of the tube. Brief injections of fluid/saline lasting for 5 s are done while Doppler signals are observed.

Patent tube is indicated by a short filling phase with rapid, steep increase in Doppler shift followed by slow uniform fall in Doppler shift. Obstruction presents as short, steep Doppler shift with no subsequent noise signals [Figure 7].

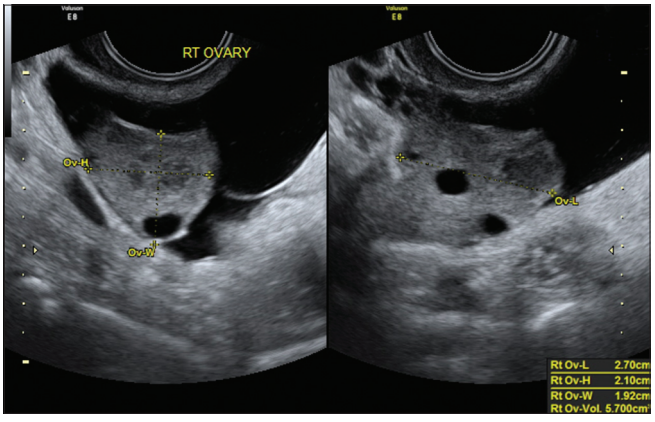

Figure 6: Fluid around the ovary, indicating free spill from fallopian tube

Using Color Doppler

Color Doppler can be used with SIS. This is more informative when injection of saline is done selectively towards one of the tubes. Under ultrasound guidance, the tip of the catheter is placed close to either cornu, one by one. First, the color box is placed on the transverse section of the uterus. Color signals following-up the uterine cavity confirm the passage of fluid in the uterus as saline is injected through the canula in the uterus in short bouts. The field of vision is immediately changed over to ovary and adnexa, by spanning the probe from transverse section of uterus, laterally. While injecting saline, color box is placed to visualize the adnexa and ovary. Filling up of the box with color signals indicates patency of the tube and absence of such signals indicate block[21] [Figure 8]. Same procedure is repeated on the opposite side. A detailed evaluation for any pathology is important immediately prior to performing the procedure as hydrosalpinx may create turbulence in the fluid present in the tube and give a false impression of a patent tube.

Adding color Doppler may increase the efficiency and accuracy of SIS for assessment of tubal patency.[22] In a study by Peters and Coloum of 129 infertile patients, Doppler SIS showed complete agreement with HSG in 81% cases. When compared with the gold standard test of tubal assessment, chromopertubation, Doppler SIS showed agreement in 86% of cases, while HSG agreed with chromopertubation only in 75% cases.[21] In a small study by Kupesic and Kurjak, 91.5% agreement was seen between color Doppler sonosalpingography and chromopertubation.[11] Correlation of color Doppler sonosalpingography and HSG with chromopertubation was 81% versus 60% respectively in one study.[10]

Combining saline with air

When air is mixed with saline, bubbles are formed and that makes saline hyperechoic and this helps better outlining of tubal lumen. This can be done either by agitating air and saline or by injecting air after saline has been already pushed in to fill up the uterine cavity and tubes [Figure 9]. The later technique was described by Jeanty *et al*. and showed 79.4% agreement with results of chromopertubation and showed a sensitivity of 85.7% and specificity of 77.2%.[22]

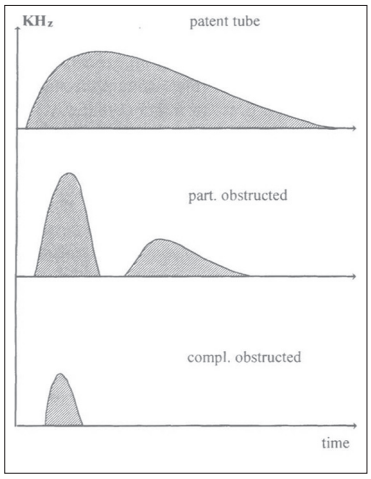

Figure 7: Diagrammatic presentation of spectral Doppler signals for tubal assessment

3D saline sonosalpingography

Transvaginal 3D saline SHSG provides good visualization of the uterine cavity and myometrial walls in three orthogonal planes. However, it does not diagnose tubal occlusion or depict architecture of the fallopian tube as accurately as X-ray HSG. Although the distal fallopian tube and fimbria were seen with real-time imaging, image the proximal tube is not satisfactorily imaged with 3D-power Doppler (PD). This technique may be reserved as an initial screening test to evaluate the uterine cavity and test tubal patency. Patients at high risk for tubal disease by history or with suspected tubal occlusion on 3D saline SHSG should be evaluated by either X-ray HSG or laparoscopy with chromopertubation.[23]

Though Kiyokawa *et al*. have shown that when 3D was added to saline salpingography the PPV, NPV, sensitivity and specificity of predicting tubal patency by were 100%, 33.3%, 84.4% and 100%, respectively. Over and above this, this method also has an advantage of assessing the shape of the uterine cavity. The full contour of the uterine cavity was depicted in 96% of cases by 3D-HyCoSy and 64% by X-ray HSG.[24]

HYCOSY

While intracavitary lesions are clearly delineated by anechoic media, very small hollow cavities, such as normal tubes are not always easily visualized using SIS.[25] Demonstration of the lumen of tubes requires visualization of movement of fluid using highly echogenic medium.[26] Hyperechogenic

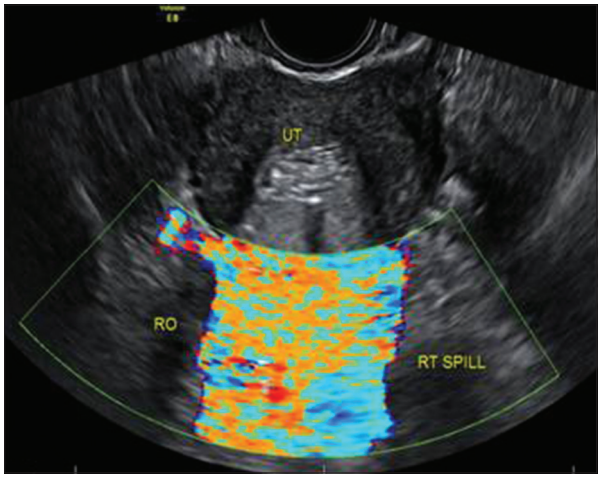

Figure 8: Patent tube filling the color box on Doppler

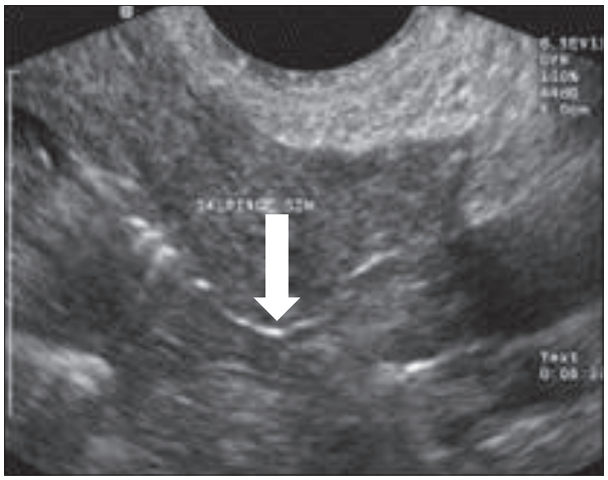

Figure 9: Tubal delineation with saline and air

contrast medium enhances echo signals and allows detection of the flow, both by B mode and Doppler ultrasound.

Experimental and clinical data suggest that insonation of echo-enhancing contrast agents with high acoustic power produces disintegration of microbubbles, resulting in a phenomenon called stimulated acoustic emission. It is based on this principle that the positive ultrasound contrast media are developed.[27]

While a cheap and cost-effective option is the use of saline mixing with air, which produce a high contrast fluid due to the presence of air bubbles. However, these bubbles stand only for a very short period and therefore tubal patency assessment may become practically difficult. Therefore, commercially available contrast media were introduced with microbubbles that can stand for a longer time.

Echovist and Levovist (Schering AG, Berlin) consist of suspension of microbubbles made of special galactose microparticles. These are suspended either in galactose solution, as in Echovist or in sterile water, as in Levovist. Just before use, these solutions are made by mixing and vigourously shaking the microparticles with the solvent and it can stand for 5-10 min. These solutions completely dissolve in the body, within about 30 min. These can be used in all patients except those with galactosemia. Non-(embryo-) toxic gel (ExEm-gel® Gynecologiq BV, Delft, The Netherlands), containing hydroxyethylcellulose and glycerol, has also been used as an intrauterine medium for sonohysterography as an alternative to saline. Gel instillation offers a more stable filling of the uterine cavity. This gel and its compounds have been tested extensively and safely used in medicine. When this gel is pushed rigorously through small openings in syringes or tubes, turbulence causes local pressure drops resulting in air dissolving in the solution and yielding foam that is stable for several minutes. ExEm-gel (containing 88.25% purified water), however, is rather viscous for passing into the Fallopian tubes. Therefore 10 ml ExEm-gel is diluted with 10 ml purified water (to give a mixture containing 94.12% water) and mixed to create foam. The mixture at this ratio created foam that is sufficiently stable to show echogenicity for at least 5 min and sufficiently fluidy to pass through patent tubes. The viscosity of this foam (270 cP) is comparable with that of Echovist (400 cP).[28]

HyCoSy is a safe outpatient procedure with a relatively low cost and its accuracy has been assessed in a metaanalysis, which compared the results of HyCoSy and laparoscopy and dye tests in 428 infertile women. Sensitivity was 93.3% and specificity was 89.7%.[29]

A meta-analysis of three comparative studies of Echovist-200, (solution of galactose and 1% palmitic acid [Echovist-Schering-AG, Germany]) including 1007 women showed that the results of HyCoSy and chromolaparoscopy were identical in 294 of 428 patients (68.7%) or in 688 of 828 individual tubes (83.1%). HyCoSy showed "false" occlusion in 85 tubes (10.3%) and "false" patency in 55 (6.7%). The results of HyCoSy and HSG were identical in 138 of 202 patients (68.3%) or in 320 of 384 individual tubes (83.3%). HyCoSy showed "false" occlusion in 49 tubes (12.8%) and "false" patency in 15 (3.9%). The findings of chromolaparoscopy and HSG agreed in 49 of 77 patients (63.6%) or in 116 of 152 tubes (76.3%). HSG showed "false" occlusion in 19 (12.5%) tubes and "false" patency in 17 (11.2%).[29]

Contrast agent that is more easily available in most countries including India, is SonoVue (Bracco). This contrast agent consists of sodium hexafluoride microparticles in normal saline. For assessment of tubal status, 1 ml of SonoVue is diluted with 4 ml of normal saline and is agitated to create foam for injection into the uterus. This contrast is safe for HyCoSy, as it is for intravascular use also. It is used as an ultrasound contrast agent for vascular studies and for diagnosis of malignancy.

This contrast appears white-echogenic on ultrasound. The scanning technique is the same as that for SIS. Using positive contrast it is possible to delineate the whole tube along with the uterine cavity even on B mode scanning [Figure 10]. There are ultrasound equipments with contrast mode (contrast tuned imaging technology based on harmonics) [Figure 11]. The advantage is that it enhances the contrast and makes visualization of tubes even better. Using contrast mode with positive contrast actually makes it easier to view the spill from the fimbrial end if the tube is patent. If the tube is not patent, the contrast column in the tube can identify the site of block.

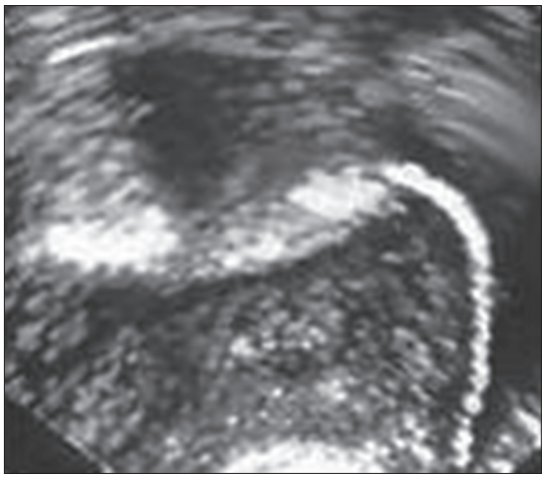

Figure 10: Positive contrast seen on B mode outlining the fallopian tube

TECHNIQUE

The technique for HyCoSy is same as for SIS. As delineation of the tube is better with HyCoSy, total amount of contrast needed is as less as 2-3 ml/tube. For diagnosis of tubal patency, two to three observation phases/tube are needed, with an observation period of continuous flow of about 10 s. Visualization of long segments of tube beyond intramural part of the tube usually indicates patency, though whole tube must be observed and spill should be confirmed. Appearance or increase in the fluid in pouch of douglas may be an indirect sign of tubal patency, same as for SIS. HyCoSy has several advantages over SIS in that it helps clearer visualization of uterine cavity, better assessment of tubal lumen and fimbriae, clearer visualization of spill and a more exact localization of site of block.

Compared to conventional HSG, HyCoSy provides a simultaneous ultrasound evaluation of pelvis and a more cost-effective evaluation of tubal pathology and can be successfully used as a first line non-invasive screening method.[30]

HyCoSy with contrast is more efficient than with saline solution in determining fallopian tube patency and is as efficient as HSG and can be used instead of HSG for screening infertile patients.[31] In a diagnostic accuracy study of HyCoSy performed with air and saline (Hydro-HyCoSy) and with contrast media (SonoVue-hyCoSy) considering HSG and/or chromopertubation as reference tests, SonoVue-HyCoSy has been found to be more accurate than Hydro-HyCoSy for the assessment of fallopian tubes.[32] While the Sensitivity, specificity and PPVs and NPVs of Hydro-HyCoSy were 91%, 71%, 55% and 95%, respectively, they were 87%, 84%, 69% and 94% respectively for SonoVue-HyCoSy. The diagnostic accuracy of Hydro-HyCoSy and of SonoVue-HyCoSy were 77% and 85%, with a Cohen's kappa of 0.52 and 0.66,

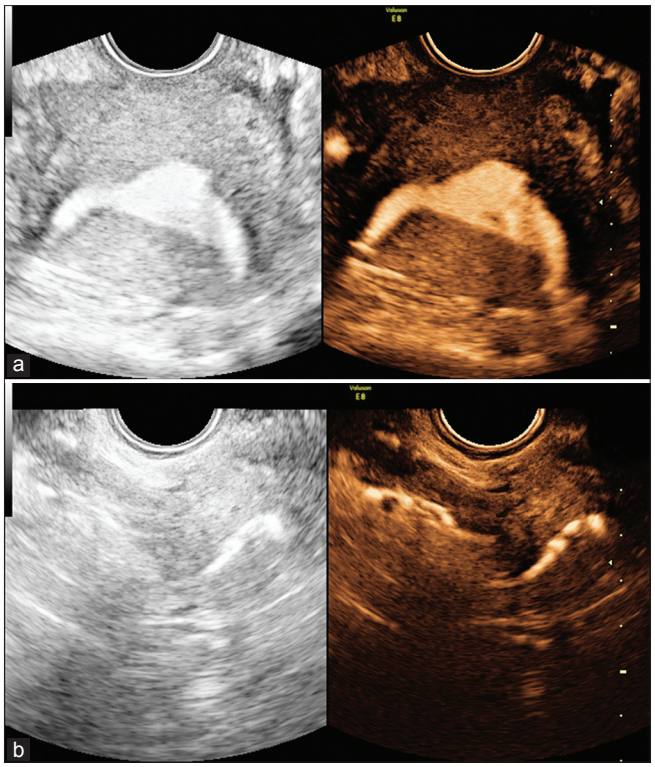

Figure 11: Contrast enhanced mode (a) showing uterine cavity, (b) showing the tube

respectively. In another small study comparing HyCoSy and chromopertubation, there was a high degree of correlation in assessing tubal patency, with sensitivity, specificity, PPV and NPV of 100%, 55.6%, 80% and 100%, respectively.[19]

Moreover, the amount contrast agent required for adequate examination was also less with positive contrast. Mean volumes of contrast injections were 35.3 ml of saline, 14.4 ml of Infoson and 13.8 ml of Iopamiron 370. Infoson-enhanced HyCoSy provided a significantly larger (P = 0.006) number of correct diagnoses (20/22 Fallopian tubes) than did saline HyCoSy (12/24 Fallopian tubes) and the same number as that achieved by HSG.[28]

In another comparative study it has been shown that Sensitivity, specificity and PPVs and NPVs of Hydro-HyCoSy were 91%, 71%, 55% and 95%, respectively, whereas for CnTI-SonoVue-HyCoSy they were 87%, 84%, 69% and 94%. The diagnostic accuracy of Hydro-HyCoSy and of CnTI-SonoVue-HyCoSy were 77% and 85%, with a Cohen's kappa of 0.52 and 0.66, respectively. CnTI-SonoVue-HyCoSy does not require a learning curve period.[31]

Yet another study has shown that HSG and HyCoSy demonstrated a high concordance with laparoscopy (83% and 80%, respectively). The two methods had a high NPV for tubal disease (HSG, 94%; HyCoSy, 88%) and the PPVs were 47% and 75%, respectively.[33]

A Study by Exacoustos *et al*. have also shown that HSG and HyCoSy had the same high concordance as laparoscopy, 86.7% and 86.7%, respectively.[34]

The study concluded that HyCoSy proved to be superior to conventional HSG in evaluating adjacent myometrial structures, adnexa and degree of follicular maturation, equal to HSG in visualizing the passage of the contrast medium into the peritoneum but inferior to HSG in imaging the fallopian tubes owing to their tortuosity.[35]

In spite of all advantages, Balen *et al*., found that both SIS and HyCoSy are insufficiently accurate and inferior to HSG.[36] They quoted a false positive rate of 9% and false negative rate of 20% for HyCoSy. This is because fallopian tubes are tortuous and usually not confined to a single plane. Moreover, distal parts of the tube may be obscured by bowel gas.

MODIFICATIONS OF HYCOSY

Additional use of pulsed wave Doppler in HyCoSy can be used as a supplement to gray-scale imaging to improve the diagnostic accuracy in cases of suspected tubal occlusion and in patients in whom intratubal flow was demonstrated only over a short distance.[12] 3D-PD helps to visualize the whole tube and spill.[37] This technique has shown to be superior to conventional HyCoSy with free spill from fallopian tubes was demonstrated in 91% of tubes using 3D-PD as compared to only 46% by conventional HyCoSy and the contrast agent required was almost half for 3D-PD in one study.[37] There are various advantages with 3D HyCoSy techniques, which allows simultaneous visualization of the uterine cavity and whole tube, short procedure time and reduced patient discomfort, requirement of less amount of contrast and storage of the 3D volume, which allows off-line review and reassessment.

TECHNIQUE OF 3D HYCOSY

SonoVue (Bracco) is used as the contrast agent. Patient preparation, catheter placement and preparation of contrast media was done according to the method described earlier. Scanning is performed using a 3D ultrasound machine (Eg: Voluson E8 Expert BT 12; GE medical Systems). A high frequency transvaginal volume probe (6-9 MHz) is used for pelvic evaluation. Contrast mode is switched on the machine. As the contrast is slowly injected through the balloon catheter into the uterus, transvaginal probe is so oriented that uterine cornu and ovaries are seen on the same plane. Having defined the contrast filling in the tubes, 3D is switched on and volumes are acquired for each side independently [Figure 12a and b].

Rendering is done in front back viewing direction. Surface enhanced mode is used. Threshold is set to make the contrast path more obvious. Magicut (Electronic scalpel) is then used to cut all shadows other than the contrast path. Then HD live rendering mode is switched on and direction of the light is adjusted to visualize the fimbriae and spill to its best. After the final picture is ready, both the halves are matched and put together to make a complete picture of uterus and both tubes [Figure 13].

In a series of 65 subfertile women in whom we performed 3D HyCosy followed by a laparoscopy and dye test to evaluate the diagnostic accuracy. The results of 3D HyCoSy was consistent with that of laparoscopy except in two women. One of these two patients had unilateral tubal block on HyCoSy, but the tube was patent at laparoscopy with injection of the methylene blue dye with pressure. In the other patient, the fimbrial end of the tube was not clearly visualized on 3D-HyCoSy and was thought to be blocked, but at laparoscopy, the distal tubal portion was buried behind the ovary due to endometriosis and the tube was patent. This technique is more informative and reliable than 2D HyCOSy. Whole extent of the tubal lumen and fimbrial condition can be visualized. Relation of fimbrial end of tube to ovary can also be defined [Figure 14].

HyCoSy with automated 3D-CCI technology retains the advantages of conventional 2D HyCoSy while overcoming the disadvantages. 2D HyCoSy is highly observer-dependent and is only accurate in the hands of experienced investigators; by obtaining a volume of the uterus and tubes, automated 3D volume acquisition permits visualization of the tubes in the coronal view and of the tubal course in 3D space and should allow less

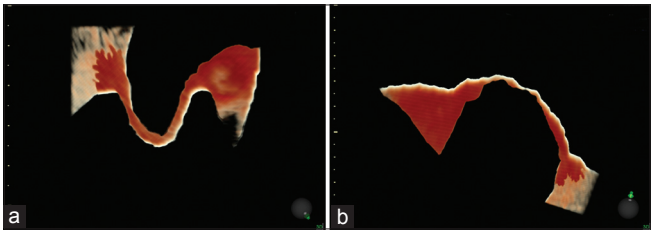

Figure 12: (a and b) 3D HyCoSy

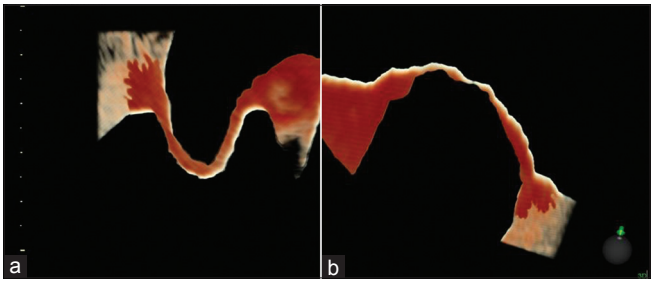

Figure 13: (a and b) Reconstructed picture of HyCoSy

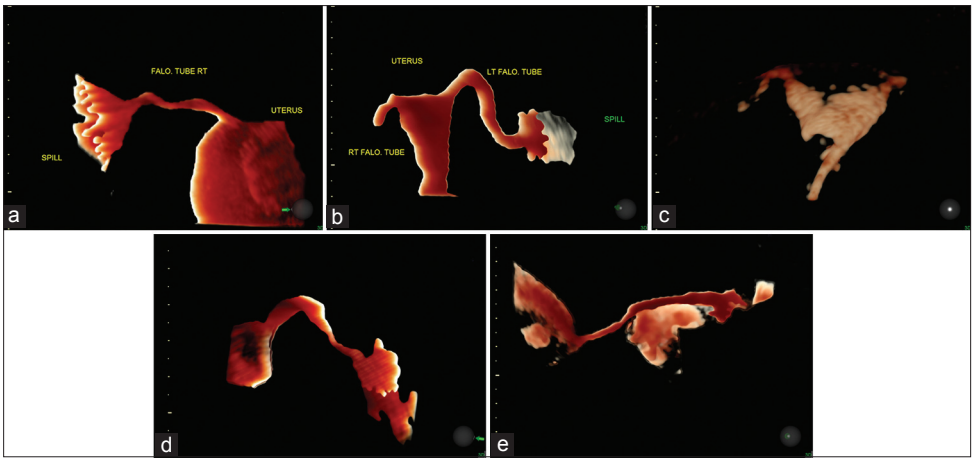

Figure 14: (a) Normal fimbrial end, (b) unilateral proximal tubal block, (c) bilateral proximal block, (d) mild proximal tubal dilatation, (e) irregular tubal lumen and fimbriae (tuberculous salpingitis)

experienced operators to evaluate tubal patency status relatively easily.[38]

Large studies have reported that 3D HyCoSy is highly accurate with 100% sensitivity, 67% specificity, 89% PPV and 100% NPV for tubal patency and concordance rate with laparoscopy of 91%.[39] In a study by Kupesic and Plavsic, 3D HyCoSy (sensitivity, specificity, PPV and NPV of 97.9%, 100%, 97.9% and 100% respectively) was found to be marginally superior to 2D HyCoSy (sensitivity, specificity, PPV and NPV of 93.6%, 97.3%, 98.2% and 97.3% respectively) for tubal assessment.[40]

It has been shown in another study that for detecting tubal patency among the 150 Fallopian tubes assessed, 3D SonoVue-HyCoSy had a sensitivity of 93.5%, specificity of 86.3%, PPVs and NPVs of 87.8% and 92.6%, respectively and diagnostic accuracy of 90.0%. The test-positive rates of 3D SonoVue-HyCoSy versus lap and dye were not significantly different (82/150 vs. 77/150, $P > 0.05$).[41] Yet another study by Chan *et al*. have shown that the sensitivity of 3D-HyCoSy for detecting tubal patency was 100% with a specificity of 67%. The PPVs and NPVs were 89 and 100%, respectively; the concordance rate was 91%. The mean duration (± standard deviation) for the 3D-HyCoSy was 13.4 ± 5.5 min.[39]

Color coded 3D-power Doppler imaging (PDI) with surface rendering allowed visualization of the flow of contrast through the entire tubal length and free spill of contrast was clearly identified in the majority of cases. The 3D-PDI method appeared to have advantages over the conventional HyCoSy technique, especially in terms of visualization of spill from the distal end of the tube, which was achieved twice as often with the 3D technique. The 3D-PDI technique allowed better storage of the information for re-analysis and archiving than conventional HyCoSy. The mean duration of the imaging procedure was less with 3D-PDI, but the operator time which included post-procedure analysis of the stored information was similar. A significantly lower volume of contrast medium (5.9 ± 0.6 ml) was used for 3D-PDI in comparison with that (11.2 ± 1.9 ml) used for conventional 2D HyCoSy.[37]

CONCLUSION

Tubal evaluation is essential in subfertile patients. HSG has been used for a long time for assessment of tubal patency. SIS has been proved to be fairly reliable technique for tubal evaluation. Its diagnostic accuracy can be improved by the use of pulse Doppler and color Doppler. Introduction of ultrasound contrast media and HyCoSy have improved the visibility of the tubal lumen. HyCoSy is accurate in determining tubal patency and evaluating the uterine cavity, suggesting it could supplant HSG not only as the first-line diagnostic test in an infertility work-up.[19]

Evaluative studies of HyCoSy showed good statistical comparability and concordance with HSG and laparoscopy combined with dye.[42] HyCoSy is well tolerated and can be a suitable alternative out-patient procedure.[43] HyCoSy using contrast agent appears to be more efficient than saline solution in detecting tubal obstruction.[44]

These studies confirm that HyCoSy is as efficient as HSG in assessing tubal patency and have the advantage of simultaneous pelvic evaluation for pelvic pathology and ovarian reserve. HyCosy can, therefore, be considered as first line investigative tool in low risk women who are not known to have any reproductive co-morbidities. HyCoSy combined with 3D ultrasound has the ability to increase the diagnostic accuracy, but this technique is not widely used because of limited availability of 3D ultrasound. While laparoscopic chromopertubation is the gold standard investigative modality for tubal assessment, it use can be

restricted to selective group of women as most women could have less invasive ultrasound methods to assess tubal patency.

To quote a few other studies that have concluded similar facts are:

- SSG can be used as an initial investigation for infertile patients and laparoscopy can be deferred for 6 months. Meanwhile endocrinological and immunological causes are ruled out and then if required laparoscopy may be done.[17]
- SSG can be used as first ambulatorial evaluation of tubal patency in infertility work up.[45]

RCOG recommends that where appropriate expertise is available, screening for tubal occlusion using HyCoSy should be considered because it is an effective alternative to HSG for women who are not known to have comorbidities. Women who are thought to have comorbidities should be offered laparoscopy and dye so that tubal and other pelvic pathology can be assessed at the same time.

Due to good degree of statistical comparability and concordance of conventional HyCoSy with HSG and laparoscopy and dye test, National Institute for Health and Clinical Excellence has recommended HyCoSy as a suitable out-patient procedure for tubal patency assessment in women who are not known to have any comorbidities such as pelvic inflammatory disease, previous ectopic pregnancy or endometriosis.[28,43] HyCoSy is well-tolerated by women and associated risks are minimal with the risk of pelvic infection is ≤ 1%.

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