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Assessment of Multidetector CT Virtual Hysterosalpingography as a Reliable Modality for the Evaluation of Female Genital System Abnormalities

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ABSTRACT

Background: virtual hysterosalpingography is a novel, noninvasive modality that combines the capabilities of multidetector CT with the established technique of hysterosalpingography to allow a simultaneous non-invasive evaluation of the entire uterine wall, uterine cavity, cervix and Fallopian tubes. The evaluation of the para-uterine pelvic structures is considered as a great advantage of the procedure that can be an alternative diagnostic technique in the infertility workup algorithm. Virtual hysterosalpingography with the reconstruction of two-dimensional, three-dimensional, and virtual endoscopic views allows a comprehensive evaluation of the female reproductive system with a single imaging test, it gives well-appointed anatomic information and a detailed characterization of the different pathologic processes. In comparison with HSG, US and MR imaging techniques that have been used for the diagnostic work-up of female infertility; virtual hysterosalpingography provides more detailed information about abnormalities of the cervix, uterus, Fallopian tubes and other pelvic structures and it may allow a more accurate evaluation of tubal patency. However, the resultant exposure of the patient to ionizing radiation is a relative disadvantage that must be weighed against the clinical purpose.

Aim of the work: this study aimed to evaluate the role of virtual CT hysterosalpingography as a new noninvasive modality for the assessment of the uterus and the Fallopian tubes abnormalities. **Conclusion:** VHSG has the ability to integrate most of the advantages of the diagnostic studies methods in the diagnosis and evaluation of the infertile female. Whether it should completely replace the use of standard conventional HSG among the infertile females, or be used as a back up to HSG and indicated when questionable or abnormal findings are encountered.

Keywords: hysterosalpingography, multidetector CT, female genital system, abnormalities.

INTRODUCTION

Evaluation of the uterus and Fallopian tubes with diagnostic imaging procedures is classically carried out using ultrasonography, conventional hysterosalpingography (HSG) and magnetic resonance imaging [(1)]. The development of multidetector computed tomography technology with a capacity for exceptionally high spatial and temporal resolution has revolutionized the examination of the heart, colon and airways [(2)]. Virtual hysterosalpingography (VHSG) is a novel, less invasive modality that combines the capabilities of multidetector CT with the established technique of hysterosalpingography to allow a simultaneous evaluation of the entire uterine wall, uterine cavity, cervix and Fallopian tubes. Evaluation of the parauterine pelvic structures is a great advantage of the procedure that could be an alternative diagnostic technique in the infertility workup [(3)]. First evaluation performed using 16-row multidetector CT (MDCT) scanners are promising, with good results for identification of uterine pathologies, but with limitations for the Fallopian tubes assessment [(4)].

The introduction of 64- row CT scanners enables isotropic spatial resolution, thinner collimation, better image quality, as well as temporal and contrast resolutions, ensuring a better voxel profile [(5)]. All these qualities give a significant improvement in the visualization and assessment of fallopian tubes, one of the major goals in the evaluation of the infertile patients [(4)]. The high spatial resolution and variety of post processing algorithms available at multidetector CT allow a more precise characterization of elevated lesions of different sizes than is possible even at hysteroscopy [(6)]. Distinct advantages over conventional x-ray HSG, convert the VHSG into a valuable alternative diagnostic technique in the infertility work up algorithm. All these qualities give a significant improvement in the visualization and assessment of the uterus and Fallopian tubes in the infertile females [(7)].

Pathology of Uterine and Tubal Abnormalities

(I)Uterine Abnormalities

A) Congenital uterine malformations: **(Behr *et al.* [(8)])**

Interruption of normal development of the Müllerian ducts can result in formation of müllerian duct anomalies (MDAs).

Classification of Müllerian duct anomalies

The American Society of Reproductive Medicine system is most commonly used to classify Müllerian duct anomalies . This system which is based on embryology, comprises seven classes (**Fig. 1)**[(8)].

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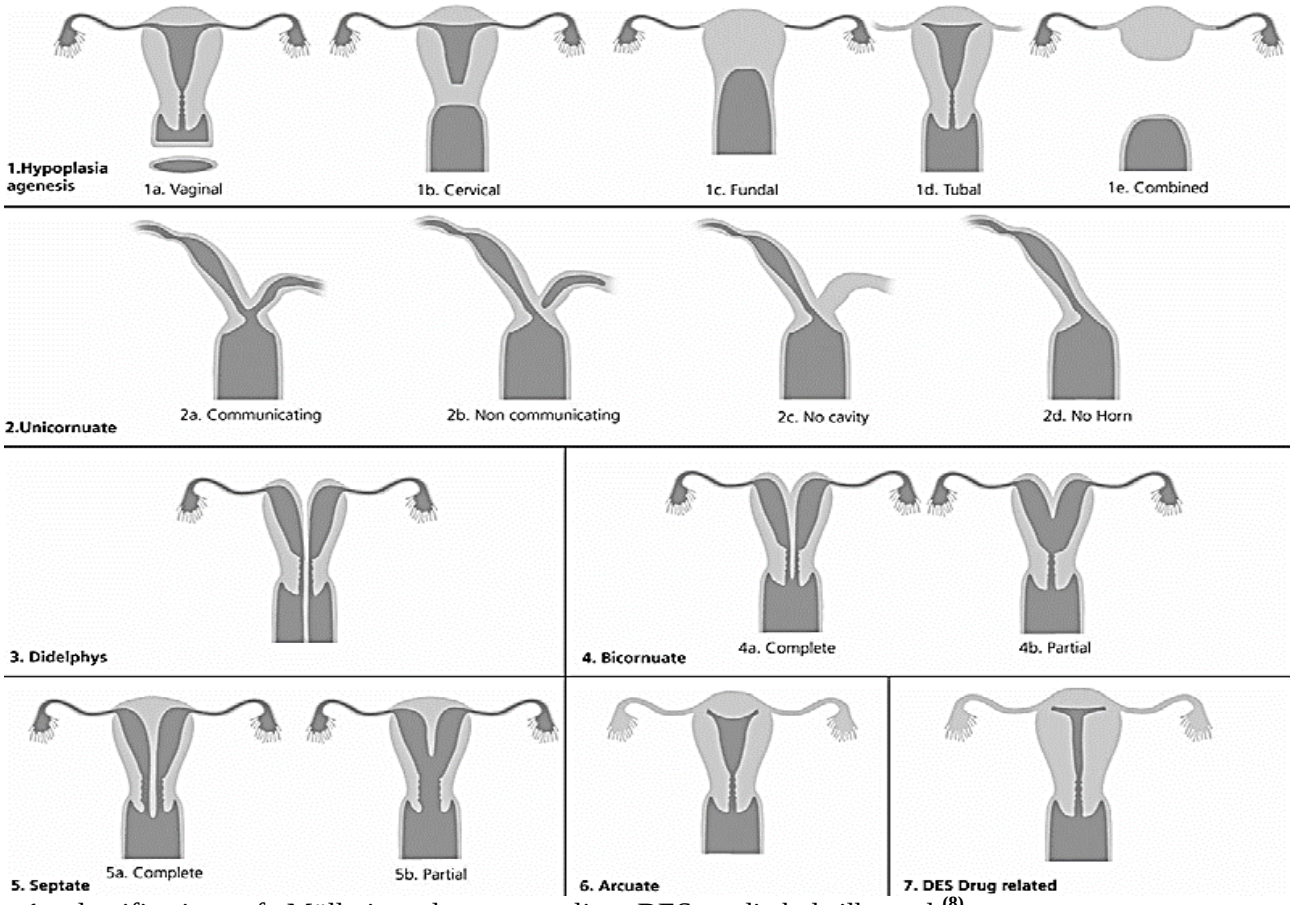

Fig. 1: classification of Müllerian duct anomalies DES = diethylstilbestrol [8].

Class I: uterine hypoplasia and agenesis

It includes hypoplasia and agenesis of the uterus and proximal vagina, which result from failed or incomplete development of both Müllerian ducts, account for 5%–10% of Müllerian duct anomalies. Patients may present with primary amenorrhea and often are initially evaluated with pelvic US or MRI, which reveals a small or absent uterus and proximal vagina [9].This anomaly is a part of the Mayer-Rokitansky-Küster-Hauser syndrome and represents the most extreme form of MDA(Complete agenesis of the proximal vagina, cervix and uterus) [8].

Class II: Unicornuate uterus

A unicornuate uterus results from normal development of one Müllerian duct and near to complete arrested development of the contralateral duct. This anomaly has four potential subtypes: a) no rudimentary horn, b) rudimentary horn with no uterine cavity, c) rudimentary horn with a communicating cavity to the normal side and d) rudimentary horn with a noncommunicating cavity. Approximately 40% of unicornuate uteri have renal anomalies ipsilateral to the rudimentary horn, with renal agenesis being the most common (67% of cases) [10].

Class III: uterus didelphys

Uterus didelphys results from complete failure of Müllerian duct fusion. Each duct develops fully with duplication of the uterine horns, cervix and proximal vagina (in three-fourths of patients) [8]. A duplicated (proximal) vagina may be associated with a transverse hemivaginal septum, resulting in ipsilateral obstruction and hematometrocolpos. Absence of vaginal obstruction, uterus didelphys is usually asymptomatic[9].

Class IV: bicornuate uterus

Bicornuate uterus results from incomplete or partial fusion of the Müllerian ducts and accounts for approximately 10% of MDAs[9].

Class V: septate uterus

Partial or incomplete septal resorption after Müllerian duct fusion results in a septate uterus, which is

the most common uterine anomaly, accounting for approximately 55% of Müllerian duct anomalies [11].

The most common diagnostic dilemma encountered in patients suspected of having an MDA is inability to differentiate between a septate and bicornuate uteri. The primary difference is the appearance of the uterine fundus; a septate uterus has a normal convex external fundal contour. A line drawn between the uterine ostia maybe used to differentiate between a septate and bicornuate uterus. In a septate uterus, the apex of the external fundal contour is more than 5 mm above the interostial line. By comparison, in a bicornuate or didelphys uterus, the apex of the external fundal contour is below or less than 5 mm above the interostial line [12].

Class VI: arcuate uterus

The arcuate uterus is normal in shape with a small midline indentation of the uterine cavity. The indentation results from the failure of the median septum to completely dissolve. This uterine anomaly is essentially normal, but is still given a distinct class [13].

Class VII: diethylstilbestrol-related uterine anomalies

Female fetuses exposed to diethylstilbestrol (DES) in utero are at risk for developing a hypoplastic, irregular, T-shaped uterus and hypoplastic and strictured Fallopian tubes and they have an increased incidence of vaginal clear cell carcinoma later in life [14].

B) Acquire uterine pathology such as:

1-Endometrial Polyps

Polyps are areas of endometrium that grow much more than surrounding endometrium. As they grow, they usually fan out, but remain attached to a small stalk. Since most polyps are small, they quite often do not cause symptoms. However, when symptoms do occur, they usually include excessive bleeding during a period, bleeding in between periods, or even spotting after intercourse [13].

2-Leiomyomas

Uterine leiomyomas (fibroids) are well-defined proliferations of smooth muscle. They are the most common benign pelvic mass lesions and the most common cause of uterine enlargement in non-pregnant women. At hysterosalpingography, submucosal fibroids are seen as filling defects with enlargement or deformity of the uterine cavity. At T1-weighted MR imaging, fibroids appear iso- to hy- pointense relative to the myometrium, whereas at T2-weighted imaging they appear homogeneously hypointense or heterogeneously hyperintense [15].

3- Intrauterine adhesions (Synechiae)

Intrauterine adhesions, or synechiae, may be the result of previous pregnancy, dilation and curettage, surgery, or infection. The increase in intrauterine surgery for myomas, septae and bicornuate uteri in recent years adds another group of patients susceptible to Intra uterine synechia (IUS). Such adhesions appear as irregular linear filling defects at hysterosalpingography [16].

Infertility secondary to uterine adhesions is known as Asherman's syndrome.

4- Adenomyosis (Internal endometriosis):

Adenomyosis, a benign pathologic condition of the uterus, is characterized by the presence of ectopic endometrial glands within the myometrium with surrounding smooth-muscle hyperplasia. At hysterosalpingography, adenomyosis is identifiable with a finding of multiple linear or saccular contrast material collections that protrude beyond the normal contour of the endometrial cavity. The endometrial cavity may appear enlarged or distorted. US and MRI may be performed if the findings at hysterosalpingography are suggestive, but inconclusive.

5-Cervical Stenosis

The term cervical stenosis is clinically defined as cervical narrowing that prevents the insertion of a 2.5 mm wide dilator. This condition may be congenital or secondary to infection or trauma. The more severe the stenosis, the more likely it is to be symptomatic. Consequences of cervical stenosis include obstruction of menstrual flow with resulting amenorrhea, dysmenorrhea and potential infertility due to inability of sperm to enter the upper genital tract. Cervical stenosis may also be a serious impediment to assisted fertility techniques including embryo transfer and intrauterine insemination. Masses such as cervical polyps, fibroids, and neoplasm also may cause narrowing of the cervical lumen [17].

(II) Fallopian Tube Abnormalities [18]

Fallopian tube abnormalities are the most common cause of female infertility, accounting for 30%–40% of cases. They include:

1. Tubal Occlusion

Fallopian tube occlusion may occur at any site along the course of the tube. The differential diagnosis of tubal occlusion typically includes tubal spasm, infection, and prior surgery.Occlusion at the ampullary end of the Fallopian tube is a condition most commonly caused by pelvic inflammatory

disease which shows tubo-ovarian abscesses, dilated fluid filled tubes (hydrosalpinx) and free pelvic fluid. At hysterosalpingography, the tube is dilated and there is absence of intraperitoneal spillover of contrast material [19].

2. Tubal Irregularity

Tubal irregularity may occur due to salpingitis isthmica nodosa, an inflammatory process within the Fallopian tube which was described as irregular benign extensions of the tubal epithelium into the myosalpinx, associated with reactive myohypertrophy and sometimes inflammation. The exact cause of this process is unknown, but its associations with pelvic inflammatory disease, infertility, and ectopic pregnancy have been reported. At hysterosalpingography, tubal irregularity and subcentimetric protrusions from the isthmic portion of the tube are seen in patients with this disease. Because tubes affected by this disease are not readily amenable to recanalization, patients typically are offered *in vitro* fertilization [19].

3. Peritubal Abnormalities

Both endometriosis and pelvic inflammatory disease may lead to peritubal adhesions with resultant infertility.

An estimated 30%–50% of women with endometriosis are infertile, and 20% of infertile women have endometriosis, a condition defined by the presence of endometrial glands and stroma outside the uterus. This condition almost exclusively affects women during their reproductive years. It may be asymptomatic or may cause multiple symptoms, including pelvic pain and infertility. Endometriosis may take the form of either small implants or cysts that change in size and appearance during the menstrual cycle and that may initiate an inflammatory response leading to fibrosis and adhesions. Endometriotic cysts, referred to as endometriomas, result from repeated hemorrhage within an implant .They generally occur within the ovary, often bilaterally [20].

Technical Method of CT Virtual Hysterosalpingography

Virtual hysterosalpingography is an emerging application that combines these capabilities of multidetector CT with the established technique of hysterosalpingography to allow a comprehensive evaluation of the female reproductive system. The primary use for virtual hysterosalpingography, as for conventional hystero- salpingography, is in the diagnostic work-up for female infertility [4].

Patient Preparation and Contraindications

No specific patient preparation is required for the examination, similar to the conventional hysterosalpingography, the prophylactic administration of antibiotics is not indicated because virtual hysterosalpingography is noninvasive and no cervical clamping is necessary, however prophylactic use of antibiotics in patients with a history of pelvic inflammatory disease (PID) is left to the referring clinicians. The examination should be performed on day 7–10 of the menstrual cycle and the patient should abstain from sexual intercourse from the cessation of menstrual bleeding until completion of the imaging examination [6].

Patient Position

For virtual hysterosalpingography, the patient is positioned supine on the CT table in the lithotomy position. First, the perineum is cleansed with a povidone-iodine solution and draped with sterile towels. Second, a disposable plastic speculum is used to dilate the vagina and obtain access to the uterine cervix, which is also cleansed with the povidone-iodine solution. A scout view of the pelvis is obtained with the speculum in place before contrast material is instilled. Next, a 10-F plastic cannula is positioned in the cervical canal, and 15 mL of an iodinated contrast material (2.5 mL iobitridol diluted with 12.5 mL saline solution) is instilled by using a power injector at a rate of 0.3 mL/sec. Scanning is initiated 45 seconds after the contrast material instillation begins and is performed by using a multidetector CT scanner [6].

CT Scan Parameters

The following technical parameters are used for image data acquisition: detector collimation, 64 × 0.625 mm; section thickness, 0.9 mm ; reconstruction interval, 0.45 mm; 120 kV; a rotation time of 0.4 seconds and scanning time, 3–4 seconds. Automatic modulation of the tube current (range, 120–250 mAs) is used to allow radiation dose saving in accordance with the patient's size along the z-axis. The acquired image data are transferred to a dedicated workstation for post processing and analysis [6].

Post processing Tools

Various post processing algorithms may be used to reconstruct images for analysis. The most

useful algorithms are multiplanar reformatting, maximum intensity projection (MIP), volume rendering, and virtual endoscopy [6].

Axial images

The first step in the analysis is the evaluation of the original axial CT images. They give an integral evaluation of the pelvic structures. An inter-median soft-tissue/bone window setting is required for the assessment of the internal and external surface of the cervix, uterus, and fallopian tubes [6].

Multiplanar Reformatting

In multiplanar reformatting, sagittal and coronal images are reconstructed with soft-tissue window settings for evaluation of the uterus, fallopian tubes, and extra uterine structures. Curved multiplanar images are reconstructed to allow assessment of the cervix, uterus, and fallopian tubes in a single continuous plane, the same window setting described earlier is utilized during the analysis.; this method allows a comprehensive evaluation of the anatomy, avoiding overlap between structures and obviating physical manipulation or retraction of the uterus [21].

Maximum Intensity Projection

This post-processing method is used to obtain three-dimensional black-and-white images of the cervix, uterus, and fallopian tubes with excellent anatomic detail. Normal fallopian tubes, which are thin and difficult to visualize on two-dimensional views, are especially well depicted on MIP images.However, the method is not useful for detecting intrauterine lesions, which may be missed [21].

Volume Rendering

This reconstruction algorithm provides three-dimensional external views of the entire female reproductive system, allowing the detection of stenosis, wall irregularities, polyps and hydro-salpinx [21].

Virtual Endoscopy

This post processing algorithm complements three-dimensional volume rendering by providing intraluminal information similar to that obtainable with hysteroscopy. Such information may enable verification of questionable findings on images obtained with other reconstruction methods [21].

Complications:

The overall risk of complications with this technique is low, compared with that at conventional hysterosalpingography. In virtual hysterosalpingography, the risks of bleeding and infection are significantly reduced because no clamping or retraction of the uterus or occlusion of the cervix is required. In addition, because the examination is painless, vasovagal reactions are extremely rare. However, there is an additional possibility of complications related to contrast agent intravasation (eg, systemic effects of an immune response). To minimize that risk, a diluted nonionic iodinated contrast agent with low osmolarity is used at virtual hysterosalpingography. A gadolinium-based contrast agent is an alternative that may be used in patients with sensitivity to iodinated contrast media [22].

Patient Discomfort

In virtual hysterosalpingography, no retraction of the uterus or manipulation of the cervix is necessary, so the examination can be performed more easily and quickly. A plastic cannula is used to allow instillation of the contrast medium through the cervix and into the uterus. The use of a power injector helps ensure a steady low pressure of instillation, and the administration of a diluted water- soluble contrast medium appears to ameliorate cellular toxic effects and peritoneal irritation. In addition, physical repositioning of the patient during imaging is not necessary for diagnostic purposes. For these reasons, virtual hysterosalpingography is less painful, more comfortable, and more easily tolerated by patients than conventional hysterosalpingography [6].

Radiation Exposure

Concern has increased about the potentially harmful effects of radiation at hysterosalpingography and pelvic multidetector CT .Knowledge about multidetector technology principles, the modification of the acquisition parameters according to the weight and size of the patient, the correct election of the best pitch and rotation time and implementation of dose modulation techniques ensure to scan with the minimum radiation dose while maintaining a diagnostic image quality, using a dose as low as reasonably achievable (ALARA) [6].

Multidetector CT protocols can be directly modified in a variety of ways to decrease the radiation dose. These include using an automated exposure control system or modifying individual acquisition parameters such as the number of phases, section thickness, peak voltage (kVp setting), tube current–time product, and pitch .

Technical Artifacts

Air Bubbles:
Air bubbles may be unintentionally introduced into the uterine cavity during hysterosalpingography. At conventional hysterosalpingography, these bubbles might be mistaken for filling defects due to polyps, blood clots, or sub mucosal myomas. At virtual hysterosalpingography, they can be identified with a high degree of confidence because of their uniform round shape, well- defined margins, and lack of internal attenuation**.** The accidental introduction of air bubbles can be avoided by carefully removing them from the syringe and cannula [(21)]**.**

Contrast Material Intravasation:
Venous or lymphatic intravasation of the contrast medium at virtual hysterosalpingography produces a reticular pattern of multiple thin hyper attenuating lines that represent opacified vessels in the uterine wall **.**Increased intrauterine pressure and recent uterine surgery are predisposing factors, but intravasation may occur even in patients without uterine abnormalities. Before the introduction of power injectors, a frequent cause of contrast material intravasation was excessive injection pressure, with the use of a power injector, the pressure is better controlled and intravasation rarely occurs [(23)]**.**

Role in Evaluating Female Genital Abnormalities

Normal Anatomical Variants
Prominent Cervical Glands
Tubular or saclike outward protrusions of the cervical wall may be observed as round high-attenuation defects at virtual hysterosalpingography. These findings, which resemble colonic diverticula, correspond to normal endocervical glands that are filled with contrast medium [(6)]**.**

Myometrial Folds:
Prominent longitudinal folds parallel to the uterine cavity are seen in some patients during virtual hysterosalpingography. These folds are remnants of the müllerian ducts, which fuse during fetal development, are not associated with endometrial disease**.**

Linear Cornual Lucencies:
The normal cornu is pear shaped and continuous with the uterus. At virtual hysterosalpingography, the cornua may appear to be separated from the uterine cavity by short linear strictures. These linear lucencies are caused by local muscle contractions. They are relatively common and are considered normal findings [(6)]**.**

I)Pathologic Findings in the Cervix:
Cervical abnormalities may include caliber changes (dilatation or narrowing), elevated lesions, and contour irregularities. Endocervical dilatation is difficult to identify, and the finding generally has little clinical significance. However, irregularities of the cervical canal must be evaluated with caution because they may represent pathologic features or normal variants [(6)]**.**

Cervical Narrowing
Narrowing of the cervical canal is usually a normal anatomic variant or a temporary occurrence related to the menstrual cycle. However, cervical stenosis also may be related to postsurgical adhesions, instrumental trauma, or a neoplasm such as a cervical leiomyoma. Whether the narrowing is focal or diffuse, it is clearly depicted on multiplanar images obtained at virtual hysterosalpingography without any cervical manipulation or retraction **(Fig. 2)** [(6)].

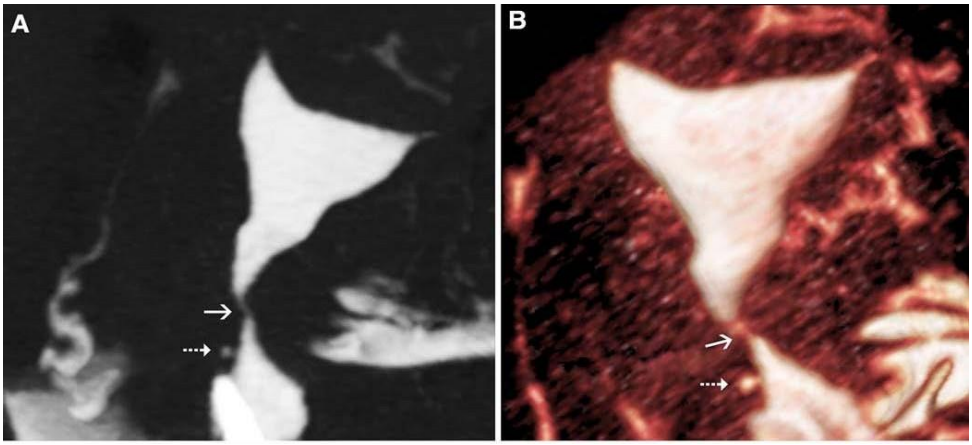

Fig. 2. A and B- Coronal MIP and volume rendering images showing a cervical glandular dilatation (dotted arrows) and cervical canal stenosis (solid arrows) [(6)].

Cervical Lesions

Elevated lesions in the cervical canal may be polyps, synechiae, congenital remnants, or sub mucosal myomas. Polyps occur infrequently in this location, but they are easily detected at virtual hysterosalpingography. Findings on the initial axial images viewed with soft-tissue window settings may be verified subsequently on virtual endoscopic views **.** Cervical synechiae, like synechiae in the uterine cavity, also may cause irregular elevated lesions that occasionally are seen in association with cervical stenosis[(21)].

II)Pathologic Findings in the Uterus:

Pathologic findings in the uterus may include anomalies of uterine size and shape as well as various elevated lesions and abnormalities of the uterine wall.

Uterine Size Anomalies:

The range of normal uterine sizes is broad, with size most often depending on the patient's age and parity. A small uterine cavity in young patients may be related to nulliparity; however, it also may be due to severe synechiae. A large uterine cavity is most frequently associated with multiparity but also may result from the presence of a large neoplasm such as a leiomyoma**.**

Uterine Shape Anomalies:

Uterine malformations include arcuate uterus which has no direct effect on fertility, unicornuate uterus, bicornuate uterus, septate uterus, and uterus didelphys. Abnormalities of uterine shape are diverse in their origin, ranging from normal variants and congenital malformations to acquired anomalies. Congenital abnormalities in uterine shape result from abnormal fusion of the müllerian ducts at an early stage of gestation (6–12 weeks after conception) [(9)].

a) Arcuate uterus

At hysterosalingography (HSG), a single uterine cavity with a broad saddle-shaped indentation at the uterine fundus is seen. Similarly, on US images a broad, smooth inward contour deformity of the uterine fundus is seen. There is a normal external contour [(24)].

b) Unicornuate uterus (Fig. 3)

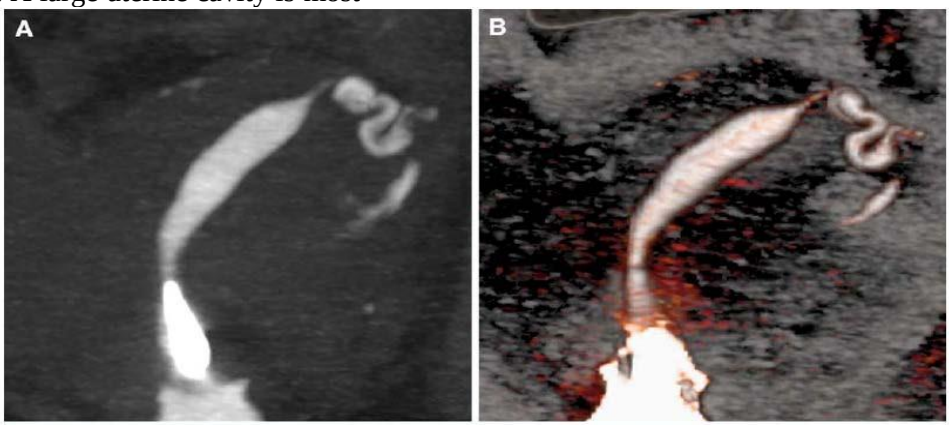

Fig. 3. Unicornuate uterus. A and B showing coronal volume rendering images demonstrating a single uterine horn. A single Fallopian tube is also visualized [(6)].

c) Bicornuate uterus

Bicornuate uterus is characterized by the presence of a cleft (>1 cm in depth at US and MR imaging) and an intercornual distance of more than 4 cm in the external contour of the uterine fundus, similar to uterus didelphys. HSG demonstrates opacification of two symmetric fusiform uterine cavities (horns) and Fallopian tubes. Historically, an intercornual angle of greater than 105° was used for diagnosis. However, imaging overlap with a septate uterus makes differentiation impossible at HSG examination. The duplicated endometrial cavity may be associated with cervix duplication (bicornuate bicollis) or be without cervix duplication (bicornuate unicollis). If a longitudinal vaginal septum is also present (one-fourth of cases), a bicornuate bicollis uterus may be indistinguishable from a uterus didelphys[(8)].

d) septate uterus

e) Uterus didelphys

The HSG demonstrates two separate, oblong endometrial cavities with contrast opacification of Fallopian tubes. The presence of an obstructed transverse septum may result in nonopacification of the ipsilateral uterine horn and is a potential pitfall leading to the misdiagnosis of unicornuate uterus [(23)].

The differentiation of fusion (didelphys and bicornuate) anomalies from reabsorption (septate and arcuate) anomalies is based on the presence of a uterine fundal cleft with fundal cleft greater than 1 cm has been reported to be 100% sensitive and specific in differentiation of fusion anomalies from reabsorption anomalies A major disadvantage of hysterosalpingography, the method most frequently used to detect congenital uterine anomalies, is its inability to show the external contour of the uterus[(24)].

Depiction of the external contour helps distinguish a bicornuate from a septate uterus, because a bicornuate uterus has a heart-shaped appearance caused by the bilobed fundus, whereas a septate uterus has a normal external appearance. At hysterosalpingography, the presence of a septate or bicornuate uterus might still be inferred from the angle between the uterine horns, with a wide or obtuse angle favoring the diagnosis of a bicornuate uterus. However, in most cases, the two anomalies have a similar appearance at hysterosalpingography, and the hysterosalpingographic findings must be correlated with US or MR imaging findings for accurate differentiation [(25)].

An advantage of virtual hysterosalpingography is its capability for evaluating the uterine wall and delineating the external uterine contour. With this capability, virtual hysterosalpingography may be more useful than other imaging techniques for achieving a precise diagnosis of congenital anomalies in a single examination [(21)].

Elevated Uterine Lesions:

Elevated lesions within the uterine cavity may be polyps, submucosal myomas, synechiae, carcinomas, or endometrial hyperplasia. An accurate diagnosis can be achieved by correlating the imaging findings with the patient's clinical and surgical history.

Endometrial Polyps:

Endometrial polyps are focal overgrowths of endometrium that usually seen at CT virtual HSG as elevated soft-tissue formations at virtual hysterosalpingography . These formations vary in size and may appear sessile or pedunculated . Polyps manifest as filling defects at hysterosalpingography and are usually difficult to distinguish from sub mucosal myomas. Therefore, small endometrial lesions are easily obscured by a large quantity of contrast material on late hysterosalpingograms. The nearly isotropic image data sets acquired at virtual hystero- salpingography permit easy detection of small lesions on multiplanar and virtual endoscopic images . The high spatial resolution and variety of post-processing algorithms available at multidetector CT may allow a more precise characterization of elevated lesions of different sizes than is possible even at hysteroscopy [(21)].

Sub mucosal Myomas (Fibroids):

Leiomyomas are benign neoplasms of the smooth muscle. When they occur in the uterus, particularly in submucosal locations, they are associated with recurrent abortion, menorrhagia, and infertility. Accurate characterization of leiomyomas is a prerequisite for optimal treatment with conservative surgery. At hysterosalpingography, sub mucosal myomas appear as well- defined filling defects that distort the uterine cavity. Small myomas may be obscured when the uterine cavity is completely opacified at hysterosalpingography. Pelvic US, although readily available and inexpensive, is highly inaccurate for the diagnosis of uterine myomas. Difficulty in establishing the correct diagnosis is due in part to the variable echogenicity of myomas and their frequent exophytic and pedunculated growth patterns, which may cause them to be mistaken for other conditions, such as polyps. It

has been suggested that hysterographic US is useful for assessing these elevated lesions. However, the method is cumbersome and although it requires uterine cannulation, it lacks the capability of virtual hysterosalpingography to provide accurate anatomic depiction of the entire uterus [(26)].

At virtual hysterosalpingography, leiomyomas appear as discrete round masses with attenuation that may be lower or higher than that of normal myometrium. submucosal myomas are easily differentiated from other types of elevated lesions with varying size at virtual hysterosalpingography. This new modality may eventually surpass both US and hysterosalpingography in its ability to help identify, localize, and characterize submucosal leiomyomas before surgery. However, MR imaging currently has the highest accuracy of any imaging technique available for this purpose [(26)].

Synechiae

Intrauterine synechiae are adhesions within the uterine cavity that are caused by scarring due to infection or trauma from invasive procedures such as dilation and curettage. The most severe manifestation is known as Asherman syndrome. The resultant endometrial abnormalities may impede the migration of sperm or the implantation of an embryo. Intrauterine synechiae can be diagnosed at virtual hysterosalpingography on the basis of characteristic findings of irregular linear, serpiginous, and angular elevated lesions within the uterine cavity [(21)].

Uterine Wall Abnormalities:

The capability of virtual hysterosalpingography for depicting the uterine wall allows rapid and easy detection of uterine enlargement, contour abnormalities, and focal masses. Subserosal and intramural leiomyomas, adenomyosis, and postsurgical changes can be recognized with a high degree of accuracy [(21)].

Leiomyomas:

Leiomyomas have various appearances depending on their size and their location within the uterine wall. As mentioned earlier, large myomas may distort the size and shape of the uterine cavity and may affect the patency of the reproductive tract by occluding the endometrial cavity or the fallopian tubes. If they do not cause obvious displacement of the uterus or tubal structures, subserosal and intramural myomas may be missed at hysterosalpingography. However, virtual hysterosalpingography clearly depicts subserosal myomas as focal masses that produce external contour abnormalities of the uterus. Intramural leiomyomas usually appear as focal masses with attenuation that differs from that of normal myometrium. Nonetheless, small lesions that have attenuation similar to that of normal tissue may be missed at virtual hysterosalpingography. Also Post treatment fistulas that formed because of necrosis in endometrial lesions treated with embolization may be depicted at virtual hysterosalpingography[(21)].

Adenomyosis

Adenomyosis is occasionally detected at virtual hysterosalpingography, if there is a connection between the ectopic endometrial glands and the uterine cavity. Adenomyosis may occur in either a diffuse or a focal pattern in the uterus. A focal adenomyoma may appear as a small diverticulum that extends into the myometrium .However, the finding is non specific, and only a small percentage of such findings represent adenomyosis. Diffuse adenomyosis manifests as multiple irregular branchlike cavities extending from the uterine cavity into the wall. Hyperplasia of the myometrium around the implants may appear as non specific uterine wall enlargement. MR imaging is more accurate than CT for the detection of adenomyomas with deep locations [(6)].

Postsurgical Changes*:*

In patients who have undergone multiple cesarean sections or similar surgical procedures, repeated disruptions of scar tissue may cause a fistula to form between the uterus and the pelvic cavity. After myomectomy for treatment of submucosal fibroids, small diverticula may be found at the resection sites in some patients [(21)].

III)Fallopian Tube Abnormalities*:*

Hysterosalpingography is considered the best imaging method for evaluating the patency of the fallopian tubes. The alternative use of US and MR imaging to assess tubal patency has been proposed. However, the normal fallopian tubes are so thin that they may elude depiction with these modalities.Virtual hysterosalpingography performed with a 64-row multidetector CT scanner not only can depict the tubal lumen and tubal wall but also allows virtual endoscopic navigation within dilated tubes. At virtual hysterosalpingography, the fallopian tubes appear as thin, smooth, tubular structures with varying degrees of tortuosity [(27)]. The appearance of the isthmic segment has been likened to that of a spaghetti noodle, whereas the ampullary segment is wider. There is substantial natural variation in the location of the tubes within the pelvis, and an unusual location is not necessarily indicative of tubal abnormality.Tubal occlusion and stenosis due to postsurgical complications or infection are common

abnormalities that are well depicted at virtual hysterosalpingography. In the presence of normal tubal patency, contrast material is seen spilling freely into the peritoneal cavity [(21)].

Tubal Occlusion

Evaluation of the patency of the fallopian tubes is a primary purpose of hysterosalpingography. Fallopian tube occlusion may result from inflammation or surgery. At virtual hysterosalpingography, occlusion appears as non opacification or abrupt cutoff of the fallopian tube and absence of intra-peritoneal spillage of contrast material. Occlusion may be unilateral or bilateral and may affect any segment of the tube. If the blockage is in the ampullary portion, the tube may become dilated, and a hydrosalpinx may form [(21)].

Hydrosalpinx

Hydrosalpinx means dilatation in ampullary portion of fallopian tube .It usually occurs as asequela of PID with agglutination and fibrosis in the peritoneal cavity surrounding the fimbria of fallopian tube [(19)].
Virtual hysterosalpingography provides a closer view of the internal anatomy of the dilated tube, supplying information similar to that obtainable at falloscopy, a micro endoscopic technique that allows direct internal examination of the tubes. virtual endoscopic navigation during virtual hysterosalpingography allows the detection of adhesions within dilated fallopian tubes[(21)].

IV)Incidental Extrauterine Findings:

Because the entire pelvis is scanned during virtual hysterosalpingography, both the uterus and the extrauterine anatomy can be evaluated simultaneously. Incidental extrauterine findings might include cystic and solid adnexal lesions , intestinal abnormalities, pelvic masses, and osseous abnormalities [(27)].

Advantages of CT Virtual Hysterosalpingography over conventional Hysterosalpingography

VHSG is very well tolerated and better accepted examination; as a matter of fact those patients that have gone through a conventional HSG before, provide input of having significantly less discomfort after having a VHSG. This is probably due to the fact that there is no instrumentation of the cervix (traction of the cervix with a tenaculum), no cervical clamping and instead of metallic cannula a specially designed well fitted plastic cannula was positioned in the external cervical OS producing less patient discomfort. also, that the completion of the study takes only a few seconds so the speed of MDCT VHSG examination reduced discomfortand anxiety, significantly shortening the patient-portion of the study and the possible discomfort that comes along with it, the dilution of contrast media during the MDCT VHSG with less irritation of the peritoneal cavity in contrast to X-ray HSG technique in which none diluted contrast media was used, also during MDCT VHSG the patient was made to remain in single position without the need to turn or change her position on the CT table in contrast to X-ray HSG where the patient was made change her position during the examination to obtain the delayed film [(4)].

Another important advantage for the MDCT VHSG was the significant dose reduction in comparison to conventional X-ray HSG,the reduction in the radiation dose during the MDCT VHSG was related to the use of automatic tube current modulation during the scan, and using small field of view consist to the region of female uterus, in contrast to X-ray HSG where multiple spot radiographs were taken, in addition to relativity lengthy fluoroscopic time during the procedure. The reconstruction of the images post-study (raw data) is known as advanced interactive reconstruction, obtaining images of excellent diagnostic quality, with the advantage of exposing the patient to a very low level of radiation in an average study (0.3–0.6 mSv) [(18)].

The evaluation of the fallopian tubes is also greatly benefited by performing a VHSG, since not only determines the morphology and patency of the tubes, but also the presence or absence of intraluminal pathology, like polyps or intratubal adhesions. In cases of hydrosalpinges, one can obtain endoscopic views, impossible to produce with other non invasive diagnostic modalities.Among the most significant advantages one can quote the lesser discomfort, less radiation and shorter time of the procedure; also, from a diagnostic viewpoint is worth mentioning the virtual endoscopic evaluation of the cervical canal, uterine cavity and fallopian tubes, as well as the assessment of the outer contour of the uterine wall [(18)].

Furthermore, The cost benefit ratio, which varies from country to country, is an important variable that should be determined on an individual basis; yet overall we are confident that VHSG has a bright future given its many diagnostic advantages [(18)].

CONCLUSION

The role of the imaging studies in the evaluation of the infertile female are significant, and contribute greatly to the diagnostic and therapeutic steps involved in the process; VHSG has the ability to integrate most of the advantages of the diagnostic methods becoming a valuable tool for the gynecologist in the evaluation and treatment of the infertile female. Whether it should completely replace the use of standard conventional HSG among infertile females, or be used as a back up to HSG, and indicated when questionable or abnormal findings are encountered.

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