INTRODUCTION

Infertility affects approximately 15% of couples ***(Stephen and Chandra, 2006).*** The demand for general infertility services showed rapid growth between 1996 and 2004, with a reported 92% increase in the number of assisted reproduction procedures ***(Wright et al., 2007)***. In association with that increase, there has been an increased demand for female infertility imaging services ***(Steinkeler et al., 2009).***

The evaluation of the uterus and fallopian tubes with diagnostic imaging procedures is classically carried out using ultrasonography, conventional hysterosalpingography (HSG), and magnetic resonance imaging ***(Krysiewicz, 1992).***

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 ***(Boiselle and Reynolds, 2002).***

Virtual hysterosalpingography 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. The evaluation of the parauterine pelvic structures is a great advantage of the procedure that could be an alternative diagnostic technique in the infertility workup ***(Carrascosa et al., 2008b).***

First evaluation performed using 16-row multidetector CT (MDCT) scanners were promising, with good results for identification of uterine pathologies but with limitations for the fallopian tubes assessment ***(Carrascosa et al., 2009).***

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 **(Rydberg et al., 2004).** 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 ***(Carrascosa et al., 2009).***

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 ***(Carrascosa et al., 2010).***

AIM OF THE WORK

The aim of the current study is to assess the role of multidetector CT virtual hysterosalpingography in the evaluation of the female reproductive tract in infertile patients.

Anatomy of Female Genital Tract

The female reproductive tract includes the following (Fig. 1&2):

1- Vagina

2- Uterus

3- Fallopian tubes

4- Ovaries

1-The vagina:

The vagina is a musculomembranous tube (7-9 cm long), which extends from the cervix of the uterus to the vestibule, the cleft between the labia minora. The vagina is usually collapsed (H-shaped in cross section) so that its anterior and posterior walls are in contact, except at its superior end where the cervix holds them apart (***Moore and Dalley, 2006)***.

Superiorly the cervix projects into its anterior wall at an acute angle. The cervix invaginates the upper vagina and divides it into a shallow anterior and deep posterior and lateral recesses or fornices. In front is the base of the urinary bladder and urethra. Behind the upper vagina is the Douglas pouch, containing loops of intestine. Below is the rectum and the anococcygeal body which separates the

lower vagina from the anal canal. On either side are the levator ani muscles and the pelvic fascia. ***(Ryan et al, 2004).***

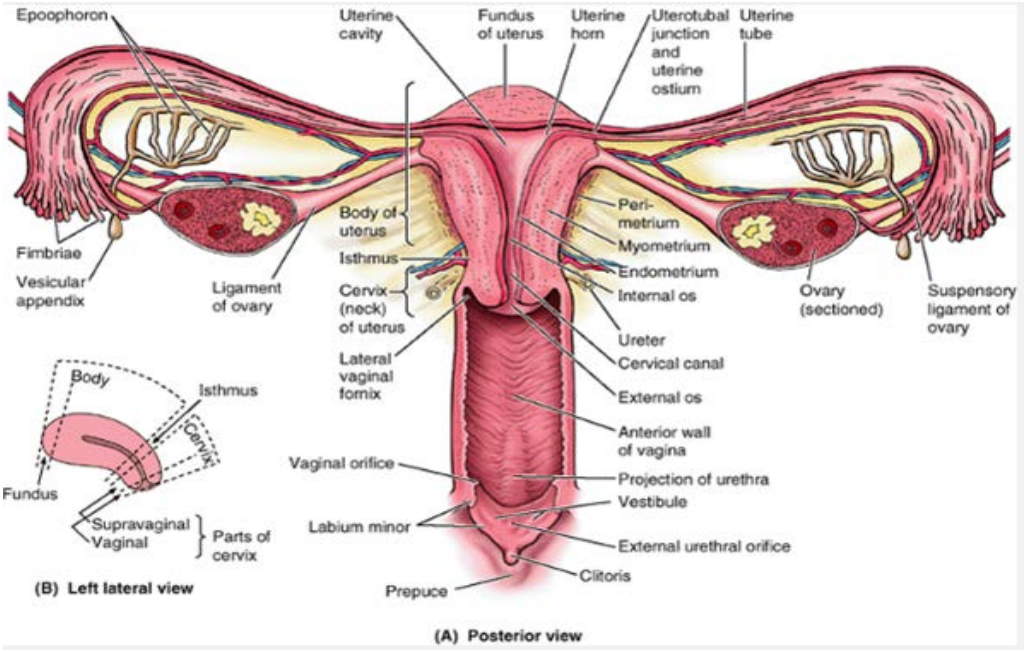


Fig. (1): Internal female genital organs. A. In this coronal section, the parts of the uterus are demonstrated, including the uterine walls, cervix, and uterine cavity. The uterine tube and ovarian ligament are attached, close together, to the lateral wall of the uterus. B. This median section of the uterus demonstrates the parts of the body and cervix, which are separated by the isthmus ***(Moore and Dalley, 2006).***

*2-**The uterus:***

It is a pear shaped muscular organ lying between the bladder anteriorly and the rectum posteriorly. It has a fundus, body and a cervix ***(Ryan et al., 2004)***.

The wall of the body of the uterus consists of three coats, or layers:

- Perimetrium “the outer serous coat”consists of peritoneum supported by a thin layer of connective tissue.
- Myometrium “the middle coat of smooth muscle” becomes greatly distended (more extensive but much thinner) during pregnancy.
- Endometrium “the inner mucous coat” is firmly adhered to the underlying myometrium. The endometrium is actively involved in the menstrual cycle, differing in structure with each stage of the cycle (***Moore and Dalley, 2006)***.

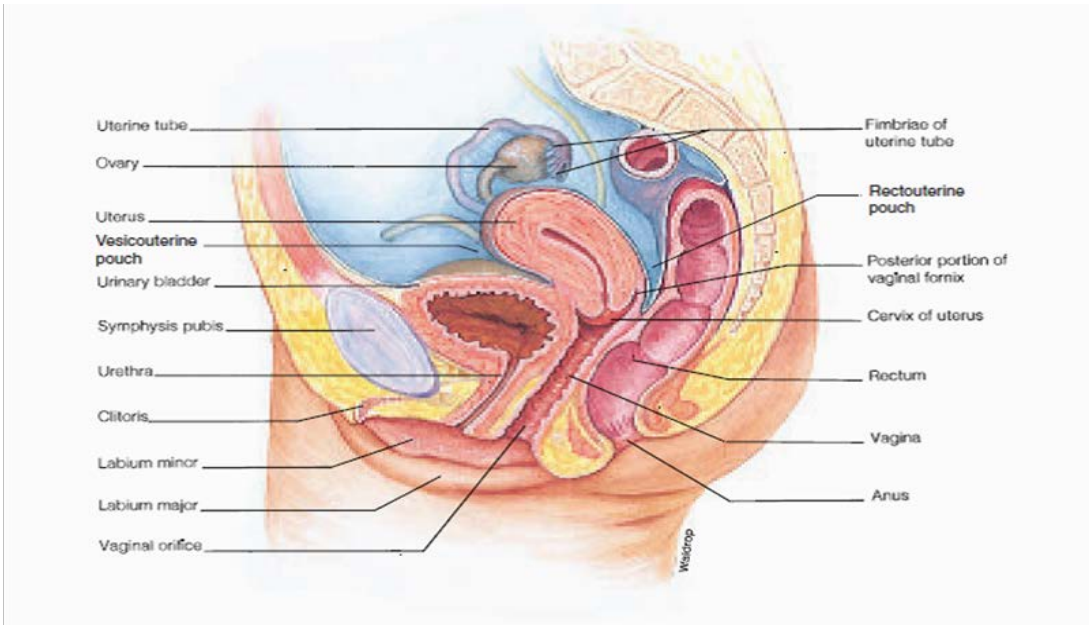


Fig. (2): Organs of the female reproductive system seen in sagittal section ***(Graaff, 2001)***

The uterus lies on the posterosuperior surface of the bladder with its cervix projecting into the anterior wall of the vagina. The cavity of the uterus is triangular in coronal section, but its anterior

and posterior walls are opposed, giving it a slit like appearance in the sagittal plane. The Fallopian tubes open in the cornua of the uterus superolateraly. The uterus leads to the vagina via the cervical canal. Just above the cervical canal, the uterus narrows to an isthmus ***(Ryan et al., 2004)***.

The internal os is at its lower end. The inner lining of the uterus is the endometrium which undergoes cyclic changes at various stages of the female life according to the hormonal status ***(Ryan et al., 2004)***.

The peritoneum covers the fundus, body, cervix and upper part of vagina posteriorly where it is reflected on the anterior surface of the rectum forming Douglas or recto-uterine pouch. Anteriorly, the peritoneum is reflected from the upper part of the body to the superior surface of the bladder forming the uterovesical pouch. On either side of the uterus, the peritoneum is reflected to the lateral pelvic walls covering the Fallopian tubes in a fold called the broad ligament. ***(Ryan et al, 2004)***.

3-Fallopian tubes:

They lie in the free edge of the broad ligament and carry ova from the ovaries to the uterus. They open in the uterine cornua. They are divided into four parts as follows:

a- Uterine part (intramural part): lies in the wall of the uterus

b- Isthmus: it is the longest and narrowest part and it leads to ampulla

c- Ampulla: it is a wide dilated tortuous part

d- Infundibilum: it is the outer extremity of the tube. It is funnel shaped and its rim is fimbriated. It extends out beyond the broad ligament and opens in the peritoneal cavity ***(Ryan et al, 2004).***

4-Ovaries:

These are paired oval organs measuring about 3x2x2 cms. They lie on the posterior surface of the broad ligament in close contact with the infundibilum of the Fallopian tube. A fold of peritoneum, the suspensory ligament of the ovary, runs from the side wall of the pelvis to the ovary. The ovarian vessels run in this ligament crossing over the external iliac vessels. Each ovary is attached to the back of the broad ligament by the meso-ovarium. A fourth attachment is the ovarian ligament, which attaches the ovary to the side of the uterus.The ovary is frequently found behind the uterus in Douglas pouch ***(Ryan et al, 2004).***

Ligaments of the Uterus:

Broad ligament:

The broad ligament of the uterus is a double layer of peritoneum that extends from the sides of the uterus to the lateral walls and floor of the pelvis (***Moore and Dalley, 2006)***.

The two layers of the broad ligament are continuous with each other at a free edge that surrounds the uterine tube. Laterally, the peritoneum of the broad ligament is prolonged superiorly over the vessels as the suspensory ligament of the ovary (***Moore and Dalley, 2006)***.

Between the layers of the broad ligament on each side of the uterus, the ligament of the ovary lies posterosuperiorly and the round ligament of the uterus lies anteroinferiorly (Fig. 3) (***Moore and Dalley, 2006)***.

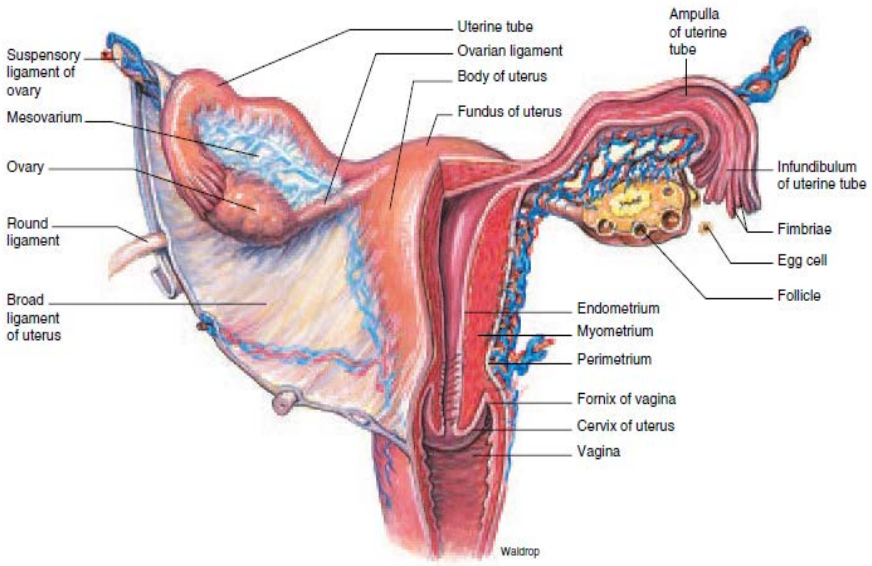


Fig. (3): Anterior view of the internal female reproductive organs ***(Graaff , 2001)***

The uterine tube lies in the anterosuperior free border of the broad ligament, within a small mesentery called the mesosalpinx. Similarly, the ovary lies within a small mesentery called the mesovarium on the posterior aspect of the broad ligament. The

largest part of the broad ligament, inferior to the mesosalpinx and mesovarium, which serves as a mesentery for the uterus itself, is the mesometrium (***Moore and Dalley, 2006)***.

The uterus and the broad ligament form a septum across the lesser pelvic cavity, dividing it into an anterior part containing the bladder and a posterior part containing the rectum, terminal ileum and part of the sigmoid colon ***(Standring et al., 2008).***

Round ligament:

Extend from the junction of uterus and tube to the deep inguinal ring and is attached at its distal extremity to the fibro-fatty tissue of the labium majora of the vulva. It lies in the anterior leaf of the broad ligament, below the uterine tubes. It is continuous with the ligaments of the ovary and the two represent, in continuity the gubernaculum, the counterpart of the gubernaculum testis of the male. It is supplied by the ovarian artery in the broad ligament and by a branch from the inferior epigastric artery in the inguinal canal. It is comprised largely of smooth muscle. Its function is to hold the fundus forward in ante version, especially when forces tend to push the uterus back (e.g., distension of the bladder, gravity during recumbence) ***(Standring et al., 2008).***

Uterosacral ligaments:

Uterosacral ligaments pass superiorly and slightly posteriorly from the sides of the cervix to the middle of the sacrum (***Moore and Dalley, 2006)***.

Transverse cervical ligaments:

The transverse cervical ligaments (cardinal ligaments, ligaments of Mackenrodt) extend from the side of the cervix and lateral fornix of the vagina to attach extensively on the pelvic wall (***Standring et al., 2008).***

Pubocervical ligament:

Fibres of the pubocervical ligament pass forward from the anterior aspect of the cervix and upper vagina to diverge around the urethra. These fibres attach to the posterior aspect of the pubic bones ***(Standring et al., 2008).***

Blood supply of the female genital tract:

- **Arterial supply:**

The arterial supply of female reproductive organs is either via the uterine or ovarian arteries (Fig. 4).

The uterine artery, which is a branch of the internal iliac, runs medially in the base of the broad ligament to the lower lateral wall of the uterus. Then it ascends tortuously within the broad ligament to supply the uterus, tubes and the vagina ***(Standring et al., 2008).***

The ovarian arteries arise from the abdominal aorta and descend along the posterior abdominal wall. At the pelvic brim, they cross over the external iliac vessels and enter the suspensory

ligaments, approaching the lateral aspects of the ovaries and uterine tubes (***Moore and Dalley, 2006)***.

- **Venous drainage:**

The venous drainage of the vagina, uterus and tubes is via venous plexus to the internal iliac vein (***Moore and Dalley, 2006)***.

The venous drainage of the right ovary is directly in the inferior vena cava via the right ovarian vein while the left ovary is drained by the left ovarian vein into the left renal vein ***(Standring et al., 2008).***

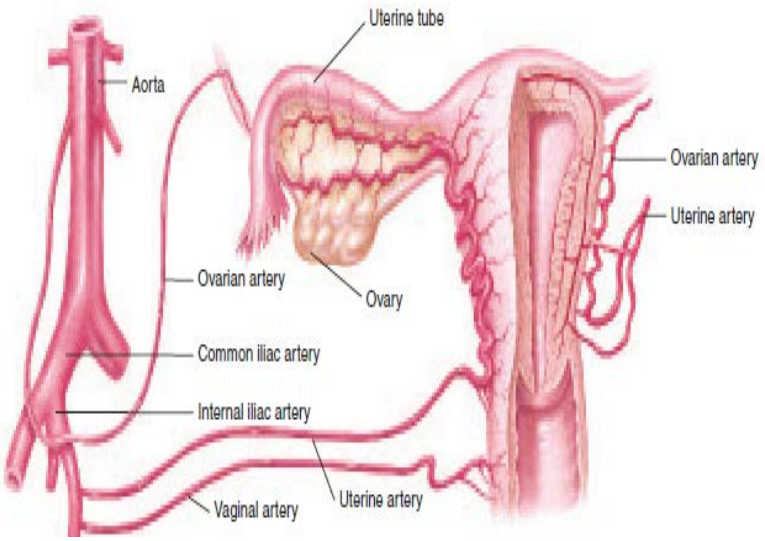


Fig. (4): Arterial supply of female reproductive organ ***(Graaff, 2001)***

Radiological CT Anatomy of the Female Genital Tract

CT examination displays the uterus as a triangular or ovoid soft tissue structure behind the urinary bladder. On unenhanced images, secretions within the endometrial canal demonstrate centrally located decreased attenuation. Following intravenous (IV) contrast medium administration, the myometrium enhances, helping to delineate the endometrium. The vagina, cervix and uterine corpus can be distinguished by morphological and enhancement pattern characteristics. The uterine corpus is typically triangular, whereas the cervix is more rounded. At the level of the fornix, the vagina is seen as a flat rectangle. The broad and round ligaments can be seen coursing laterally and anteriorly, respectively. In the premenopausal patient the normal ovaries are routinely seen, usually postero-lateral to the uterine corpus (Fig. 5 & 6). Their uniform soft tissue density is punctuated by small cystic regions representing follicles ***(Allison et al., 2008).***

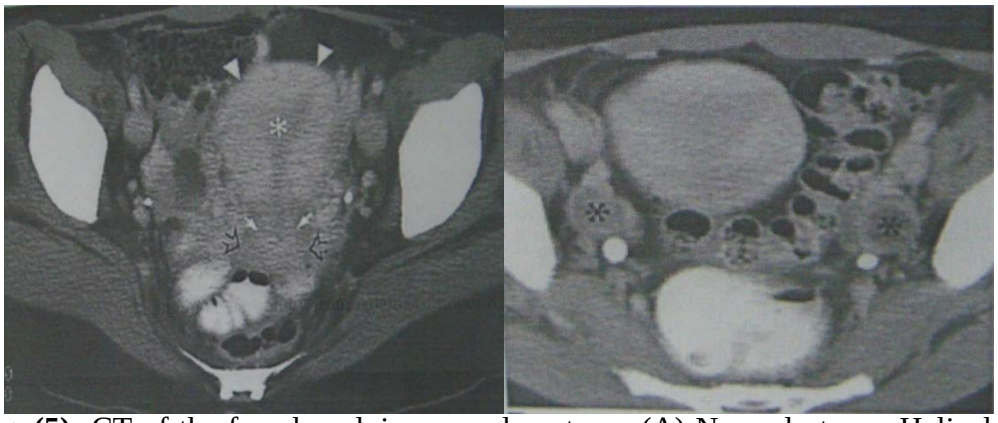
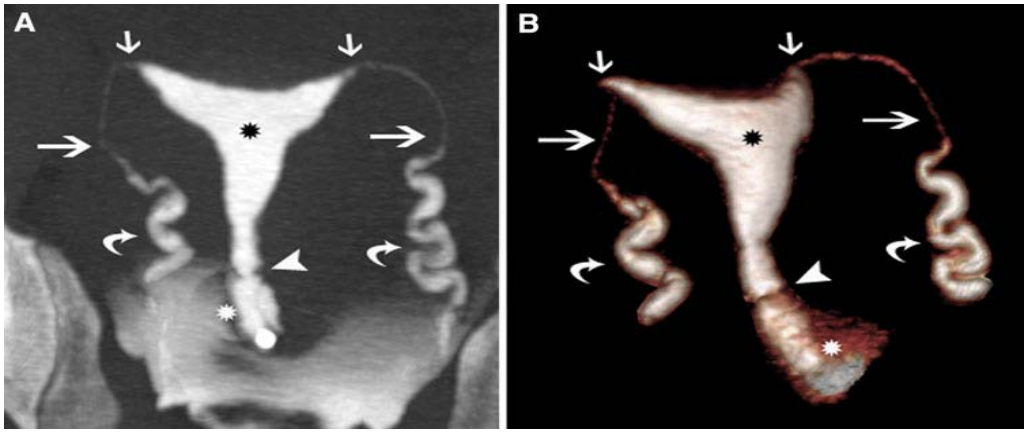


Fig. (5): CT of the female pelvis: normal anatomy (A) Normal uterus**.** Helical CT of the normal uterus and adnexa shows the low attenuation endometrial canal (*) flanked by enhancing myometrium (arrowheads). Enhancing endocervical mucosa (short solid white arrows) surrounds the endocervical canal. The fibrous cervical stroma (open black arrows) enhances less than the uterine corpus myometrium. A physiological cyst is seen in the right ovary. (B) Normal ovary. Helical CT shows bilateral physiological ovarian cysts (*). The ovaries are in their expected location, anterior to the internal iliac vessels and posterior to the external iliac vessels. The zonal anatomy of the uterus is faintly defined ***(Allison et al., 2008).***

Fig. (6): Multi-detector CT virtual hysterosalpingography (MDCT VHSG):



Normal anatomy. The uterus has an inverted triangular shape. The isthmus (arrowhead) is the transition between the cervix (white asterisk) and the uterine body (black asterisk). The Fallopian tubes can be divided into three segments: interstitial (short arrow), isthmic (long arrow), and ampullary (curved arrow). (A) Maximum intensity projection. (B) Volume rendering reconstruction ***(Carrascosa et al., 2010).***

Pathology of Uterine and Tubal Causes of Infertility

Infertility is defined as the inability of getting pregnant after trying for at least one year, without use of birth control means and while having normal sexual intercourse. Assisted reproduction includes all the methods used for fertilization, which is not achieved through sexual intercourse (***Ombelet et al., 2008).***

Infertility seems to be a multidimensional health issue which occurs not only due to health problems related to the Fallopian tubes, the ovaries, and the uterus, but it may also be a result of the choices imposed by the modern lifestyle, like the higher average age of people who get married, stress and others (***Roupa et al.,2009).***

Uterine Abnormalities:

The uterus is the final destination for the embryo and the place where the fetus develops until delivery. Therefore, uterine factors may be associated with infertility or with pregnancy wastage and premature delivery. Uterine factors can be congenital or acquired. They may affect the endometrium or the myometrium and are responsible for 2-5% of infertility cases ***(Garcia et al., 2006)***.

Problems of the uterus and uterine lining that can cause or contribute to reproductive problems such as infertility are: