INTRODUCTION

Infertility is among the most widespread women's health challenges in the developing countries. At the same time not much attention is paid to it ***(Leke, 2002).***

Infertility is a complex disorder with significant medical, psychological and economic problems. Approximately 15 % of couples are affected by infertility, which is defined by WHO as the inability of a couple to conceive after 12 months or more of regular unprotected sexual intercourse ***(Pundir and El Toukhy, 2010).***

It is generally considered appropriate to evaluate a couple for causes of infertility after 1 year of failed attempts at conception. However, given the inverse relationship of female fertility with age, it is often recommended that women over 35 years of age be evaluated after 6 months of failure to conceive, and women older than 40 be evaluated immediately ***(McLaren, 2012).***

Infertility is primary if the couples had never been pregnant, whereas secondary infertility is the inability to get pregnant after an earlier pregnancy which may or may not have led to live birth ***(Abubakar and Yusuf, 2014).***

A variety of factors may affect normal fertility including patient age, anatomy, ovulatory status, and sperm quality. Potential causes of infertility can be divided into male and female causes and include endocrine, anatomic, genetic, and behavioural conditions ***(Sadow and Sahni, 2014).***

Common causes of infertility include male factor (45 %), ovulation disorders (37 %) and tubal damage (18 %) ***(Farhi and Ben-Haroush, 2011).*** A combination of several factors is found in approximately 20 % of all couples ***(Sotrel, 2009).***

Hysterosalpingography (HSG) provides a unique combination of both fallopian tube and uterine cavity evaluation. A comprehensive understanding of both HSG and correlative cross-sectional imaging findings are essential radiologic skills ***(Karyn et al., 2015).***

Hysterosalpingography is a minimally invasive procedure with rare complications and a relatively quick procedure that can provide information on a variety of conditions which cause infertility.

It has also been suggested that Hysterosalpingography has a therapeutic role in enhancing sub fertility ***(Phaylim et al., 2011).***

Other imaging modalities which play vital roles in assessing infertility in females include ultrasound and magnetic resonance imaging. Trans-vaginal ultrasound scan is a standard

first choice procedure, which could be complemented by saline or hysterosalpingo contrast sonography (HyCoSy). This has been found to be highly sensitive, specific and accurate in identifying uterine abnormalities or polyps but has limited value in the assessment of tubal abnormalities.

Magnetic resonance imaging is also limited in its role in fallopian tube assessment but is valuable in evaluating congenital Müllerian duct anomalies and uterine wall lesions. Hysteroscopy and laparoscopy are other complementary but invasive and expensive procedures for fallopian tubes, uterus and cervix evaluation ***(Balen, 2000).***

AIM OF THE WORK

To evaluate the spectrum of radiological diagnostic findings in Hysterosalpingography (HSG) examinations performed at Ain shams university hospitals and to determine the structural and pathological pattern of the fallopian tubes and uterus on hysterosalpingography (HSG) examination in cases of female infertility and their prognostic significance.

Chapter 1
EMBRYOLOGY AND ANATOMY OF THE FEMALE INTERNAL GENITAL ORGANS

The development of the female reproductive system is closely related to the development of the urinary system. The early development of the gonads, both female and male, takes place towards the 4th week of gestation in the form of a projection from the genital ridge, composed of a thickening of celomic epithelium. However, up to the 6th week of gestation the gonads remain undifferentiated and the mesonephric and paramesonephric ducts coexist.

At the 6th-7th week the male genes located on the Y chromosome or the female genes located on the X chromosome encode for the production of inducers which begin the differentiation of the primitive gonads into testicles or ovaries, respectively. In particular, a sequential development occurs in the female gonads of two types of cords: medullary and cortical. The latter give rise to the germ cells which will become definitive follicles ***(Sadler, 2009).***

The müllerian ducts are paired embryologic structures that undergo fusion and resorption in utero to give rise to the uterus, fallopian tubes, cervix, and upper two-thirds of the vagina. Interruption of normal development of the müllerian

ducts can result in formation of müllerian duct anomalies (MDAs) ***(Behr et al., 2012).***

In females the paramesonephric ducts form the uterine tubes, the uterus and the superior part of the vagina, whereas the mesonephric ducts atrophy. For this to happen, the presence of the ovary is not required, in that there is a spontaneous tendency towards feminization. In contrast, in males the testicles secrete an inhibitory substance which opposes the spontaneous tendency towards feminization and causes atrophy of the paramesonephric ducts and formation of the ductus deferens, the seminal vesicles and the mesonephric ducts ***(Sadler, 2009).***

To simplify the embryologic process, we adopted the three-stage approach which is ductal development, ductal fusion, and septal reabsorption.

Interruption of müllerian duct development during this time gives rise to aplasia or hypoplasia of the vagina, cervix, or uterus.

Interruption of the müllerian duct fusion process gives rise to bicornuate uterus and didelphys MDA subtypes, and finally interruption of müllerian duct development during the reabsorption phase gives rise to septate or arcuate MDA subtypes ***(Robbins et al., 2012).***

During their development the female gonads also undergo a change of site (descent of the ovaries), albeit to a

lesser extent than the male gonads. By the third month of gestation the ovaries have arrived in the lumbar region of the greater pelvis, and later, during the first year, they reach their final destination in the pelvic cavity.

In the following weeks up to birth the production of hormones continues, but at a decreasing rate. Afterwards the gonads begin a period of quiescence, to then become active again at puberty, with the awakening of specific sexual neurosecretion ***(Sadler, 2009).***

1) Anatomy of the uterus

The uterus is a hollow pyriform muscular organ situated in the pelvis between the bladder in front and the rectum behind.

Position: Its normal position is one of the anteversion and anteflexion **(Figure 1).** The uterus usually inclines to the right (dextrorotation) so that the cervix is directed to the left (levorotation) and comes in close relation with the left ureter ***(DC DUTTA's, 2013).***

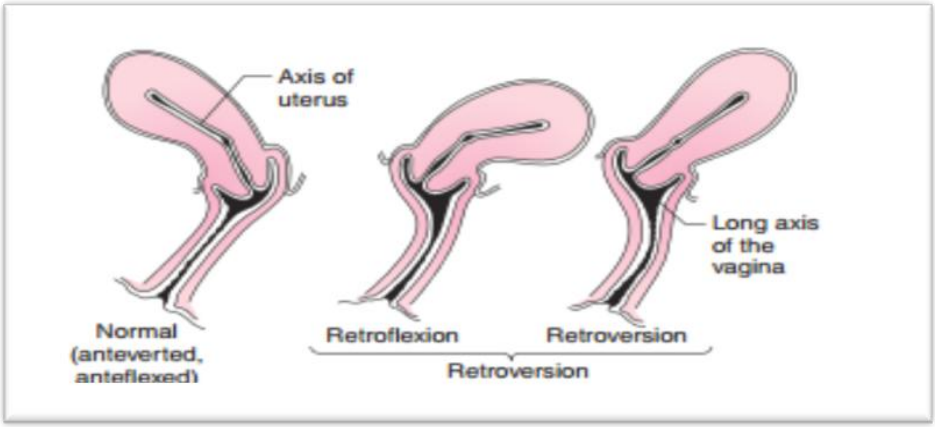

Figure (1): Position of the uterus. Anteverted, anteflexed uterus (normal position) and retroverted uterus ***(Howkins and Bourne, 2015)***.

The uterus is divided anatomically and functionally into body, isthmus and cervix **(Figure 2)**.

The line of division corresponds to the level of the internal os, and here the mucous membrane lining the cavity of the uterus becomes continuous with that of the cervical canal.

At this level the peritoneum of the front of the uterus is reflected on to the bladder, and the uterine artery, after passing almost transversely across the pelvis, reaches the uterus, turns at right angle and passes vertically upwards along the lateral wall of the uterus.

The cervix is divided into vaginal and supravaginal portions. The fundus of the uterus is that part of the corpus uteri which lies above the insertion of the fallopian tubes**.** The uterus is capable of distension during pregnancy, as well as with

distended media during hysteroscopic examination, Otherwise the two walls are in opposition ***(Howkins and Bourne, 2015)***.

The uterus consists of three layers: the outer serous layer (peritoneum), the middle muscular layer (myometrium) and the inner mucous layer (endometrium) ***(Ash Monga, 2006).***

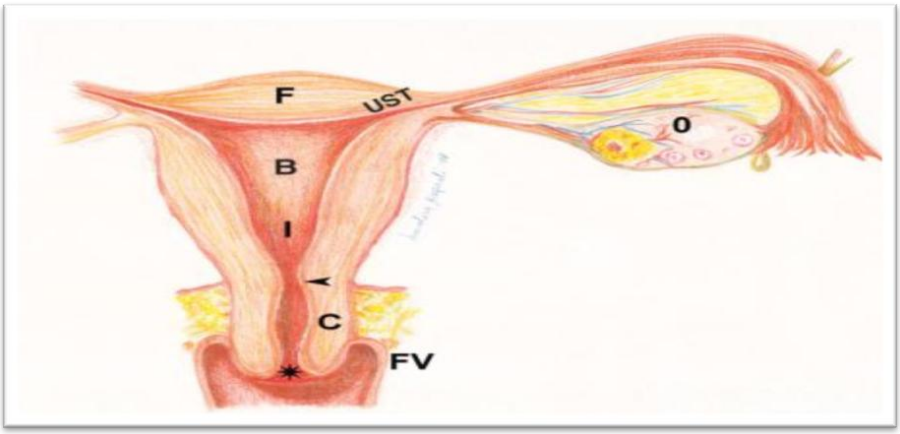

Figure (2): Anatomic diagram of the uterus. Coronal section. The **arrowhead** indicates the internal uterine os, the **asterisk** the external uterine os. **B**, body; **C**, cervix; **F**, fundus; **FV**, fornix vaginalis; **I**, isthmus; **O**, ovary; **UST**, uterine segment of tube ***(Olivetti el al., 2009).***

Arterial Blood supply (Figure 3): The arterial supply is from the uterine artery—one on each side. The artery arises directly from the anterior division of the internal iliac or in common with superior vesical artery. The other sources are ovarian and vaginal arteries to which the uterine arteries anastomose. The uterine artery crosses the ureter anteriorly about 1.5 cm away at the level of internal os before it ascends up along the lateral border of the uterus in between the leaves of broad ligament.

Venous drainage: The venous channels correspond to the arterial course and drain into internal iliac veins ***(DC DUTTA's, 2013).***

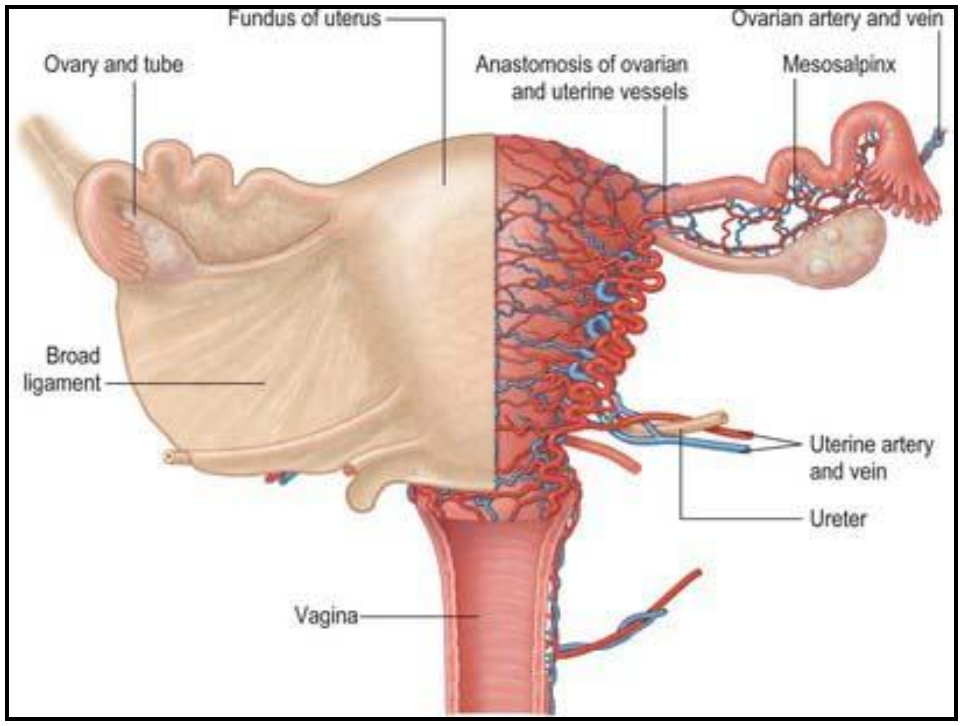

Figure (3): Blood supply of the uterus ***(Drake et al., 2008).***

2) Anatomy of the fallopian tubes

The uterine tubes are paired structures, measuring about 10 cm (4 inch) and are situated in the medial three fourth of the upper free margin of the broad ligaments.

Each tube has got two openings, one communicating with the lateral angle of the uterine cavity, called uterine opening and measures 1 mm in diameter, the other is on the lateral end of the

tube, called pelvic opening or abdominal ostium and measures about 2 mm in diameter ***(DC DUTTA's., 2013).***

The Fallopian tube runs in the upper margin of the broad ligament, part of which, known as the mesosalpinx, encloses it so that the tube is completely covered with peritoneum except for a narrow strip along this inferior aspect. It is described in four parts **(Figure 4):**

The **interstitial** portion lies within the wall of the uterus; the **isthmus** is the narrow portion adjoining the uterus. This passes into the widest and longest portion, the **ampulla**. This in turn terminates in the extremity known as the **infundibulum**, where the funnel-shaped opening of the tube into the peritoneal cavity is surrounded by finger-like processes, called fimbriae, into which the muscle coat does not extend.

The inner surfaces of the fimbriae are covered by ciliated epithelium, which is similar to the lining of the fallopian tube itself. One of these fimbriae is longer than the others and extends to, and partly embraces the ovary ***(Ash Monga, 2006).***

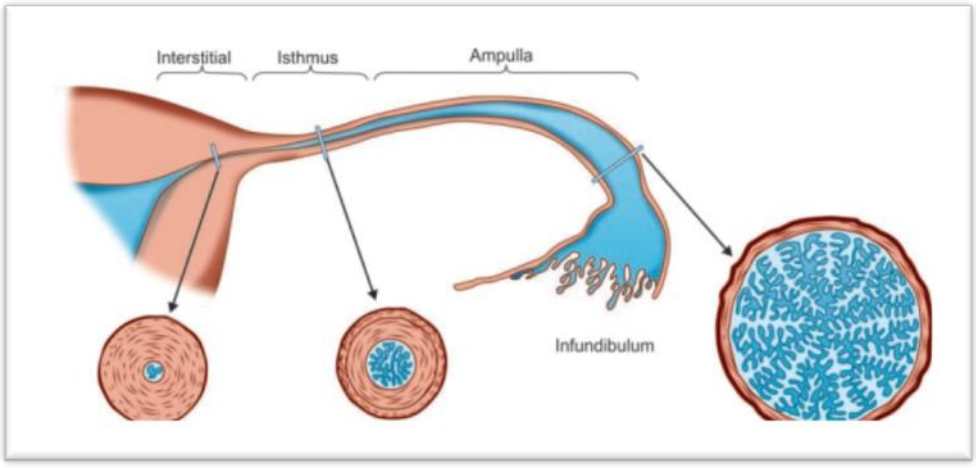

Figure (4): Cut section through the tube showing complex mucosal pattern ***(DC DUTTA's, 2013).***

The fallopian tube represents the cranial end of the Müllerian duct, and its lumen is continuous with the cavity of the uterus. Consequently, spermatozoa and the fertilized ovum can pass along the tube. Fluids such as dyes and gases such as carbon dioxide may be injected through the uterus and by way of the fallopian tubes into the peritoneal cavity, and by these means the patency of the fallopian tubes can be investigated clinically by dye test.

The blood supply of the fallopian tube is mainly derived from the tubal branches of the ovarian artery, but the anastomosing branch of the uterine artery supplies its inner part.

Unlike the vermiform appendix, the fallopian tube does not become gangrenous when acutely inflamed, as it has two sources of blood supply which reach it at opposite ends.

The lymphatics of the fallopian tube communicate with the lymphatics of the fundus of the uterus and with those of the ovary, and they drain along the infundibulo-pelvic ligament to the para-aortic glands near the origin of the ovarian artery from the aorta. Some drain into the pelvic glands ***(Howkins and Bourne, 2015).***

Nerve supply: The nerve supply is derived from the uterine and ovarian nerves. The tube is very much sensitive to handling ***(DC DUTTA's, 2013).***

Chapter 2
RADIOLOGICAL ANATOMY AND TECHNIQUE OF HYSTEROSALPINGOGRAM

Hysterosalpingography (HSG) refers to the radiographic evaluation of the uterine cavity and fallopian tubes after injection of a radio-opaque contrast medium through the cervical canal. It is commonly the initial investigation for evaluating fallopian tube disorders associated with infertility ***(Abdullah et al., 2001)***.

Indications for the examination include infertility and recurrent miscarriage, fistulae of the genital system, congenital uterine anomalies (unicornuate, bicornuate, septate, didelphic, hypoplastic uterus), acquired uterine anomalies (submucous myomas, endometrial polyps, intracavitary synechia) and suspected alterations of the uterine tubes (proximal or distal occlusions, tuberculosis, peritubal adherences).

Contraindications include metrorrhagia, acute and subacute inflammation of the pelvic cavity, allergies to contrast media, and of course pregnancy.

Complications associated with the procedure include bleeding and infection.

Some patients may report pelvic discomfort following catheter placement, which may be intense to the point of interrupting the examination. Rare complications include

vasovagal reactions, and even less frequently adverse reactions to the contrast medium ***(Simpson et al., 2006).***

While there may be slight variations in HSG technique between institutions, there are several acceptable methods of obtaining diagnostic results ***(Ott et al., 1998).***

Timing: The examination is preferably performed between the 8^{th} and 12^{th} day of the menstrual cycle, or at any rate after the cessation of menstrual flow and prior to ovulation.

In this time window pregnancy is unlikely and the endometrium is thin, which facilitates interpretation of the radiologic images ***(Simpson et al., 2006).***

Technique: The patient is placed on the fluoroscopy table in a lithotomy/modified lithotomy position. The patient is draped and a speculum is inserted to obtain visualization of cervix.

The cervix is then cleansed with iodine solution soaked gauze and secured by a tenaculum.

Either a metal cannula with a small acorn tip or a balloon-tipped catheter can be used for the procedure.

Either system should be fully flushed with contrast prior to insertion to avoid air bubble artifacts.