INTRODUCTION

Infertility is defined as one year of unprotected intercourse that does not result in pregnancy ***(Makar and Toth, 2002)***.

In recent years, demand for infertility services and treatment of infertility has increased. Laparoscopy, hysteroscopy and hysterosalpingography are the most effective techniques currently used to evaluate female pelvic disorders related to infertility. Also, transvaginal ultrasonography (US) has been the foremost imaging modality for assessing female genital tract ***(Dykes et al., 2007)*.**

Magnetic resonance (MR) imaging has also been used for over 10 years to the problems associate with female infertility. There are many advantages of MR imaging, 1st is the non-use of ionizing radiation, which is an important consideration in women of reproductive age. Another advantage is that MR imaging is less invasive and less observer dependent than classic imaging techniques. Furthermore, recent advances in MR imaging with the phased-array coil has created further imaging possibilities, resulting in excellent spatial and tissue contrast resolution, multi-planar capability and fast techniques ***(Izumi et al., 2003)*.**

The causes of female infertility include ovulatory disorders (i.e., Pituitary adenoma and polycystic ovary syndrome), disorders of the fallopian tubes (i.e., hydrosalpinx), pelvic inflammatory disease, uterine disorders (i.e., Müllerian duct anomalies, adenomyosis and leiomyoma), and pelvic endometriosis ***(Farquhar, 2009).***

MR imaging is used in a variety of clinical settings in diagnosis, treatment and management. The applications of MR imaging include evaluation of the functioning uterus and ovaries, visualization of pituitary adenoma, differentiation of Müllerian duct anomalies and accurate non-invasive diagnosis of adenomyosis, leiomyoma and endometriosis ***(Freeman-Walsh et al., 2008).***

In addition, MR imaging helps to predict the outcome of conservative treatment for adenomyosis, leiomyoma and endometriosis and may lead to selection of better treatment plans and management. Finally, MR imaging may serve as an adjunct to diagnostic laparoscopy and hysterosalpingography in patients with hydrosalpinx, peritubal adhesions or pelvic adhesions related to endometriosis ***(Izumi et al., 2003)***

AIM OF THE WORK

Our aim is to provide an overview of the capabilities and potential MR imaging for diagnosis, treatment and management of female infertility.

ANATOMY AND PHYSIOLOGY OF FEMALE REPRODUCTIVE SYSTEM

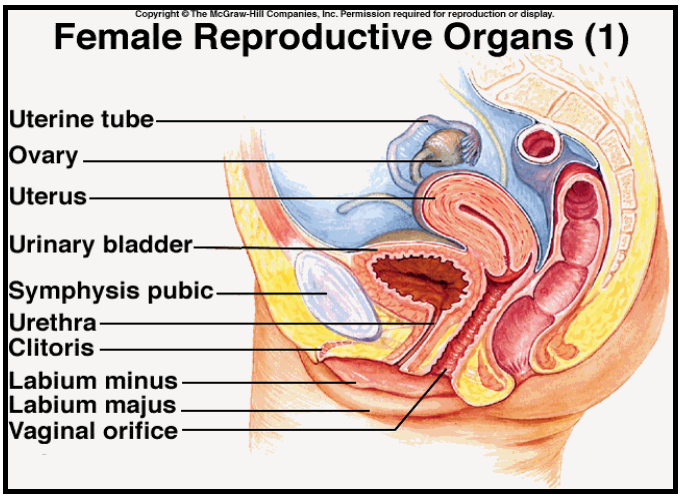

Fig. (1): Anatomy of female reproductive organs
(Quoted from Marieb and Katja, 2006).

Female genital system has three basic functions:

- Reproduction.
- Production of eggs (ovulation).
- Production of female sex hormones ***(Godwin, 2004).***

The internal organs of the female consists of the uterus, vagina, fallopian tubes, and the ovaries.

Uterus:

The uterus is a hollow organ about the size and shape of a pear, it is the organ of menstruation and during pregnancy it receives the fertilized ovum, retains and nourishes it until it expels the fetus during labor ***(Rayan et al., 2005).***

Location: The uterus is located between the urinary bladder and the rectum (fig 1). It is suspended in the pelvis by broad ligaments.

Divisions of the uterus: The uterus consists of the body or corpus, fundus, cervix, and the isthmus. The major portion of the uterus is called the body. The fundus is the superior, rounded region above the entrance of the fallopian tubes. The cervix is the narrow, inferior outlet that protrudes into the vagina. The isthmus is the slightly constricted portion that joins the corpus to the cervix ***(Rayan et al., 2005)***

Walls of the uterus: The walls are thick and are composed of three layers:

- The endometrium is the inner layer or mucosa. A fertilized egg burrows into the endometrium(implantation) and resides there for the rest of its development. When the female is not pregnant, the endometrial lining sloughs off about every 28 days in response to changes in levels of hormones in the blood. This process is called menses.
- The myometrium is the smooth muscle component of the wall. These smooth muscle fibers are arranged in longitudinal, circular, and spiral patterns, and are interlaced with connective tissues.

- The perimetrium is a strong, serous membrane that coats the entire uterine corpus except the lower one fourth and anterior surface where the bladder is attached ***(Rayan et al., 2005).***

Vagina:

- **Location:** The vagina is the thin in walled muscular tube about 6 inches long leading from the uterus to the external genitalia. It is located between the bladder and the rectum.
- **Function:** The vagina provides the passage for childbirth and menstrual flow.

Fallopian Tubes (Two):

- **Location:** Each tube is about 4 inches long and extends medially from each ovary to empty into the superior region of the uterus.
- **Function:** The fallopian tubes transport ovum from the ovaries to the uterus. There is no contact of fallopian tubes with the ovaries.
- **Description:** The distal end of each fallopian tube is expanded and has finger-like projections called fimbriae, which partially surround each ovary. When an oocyte is expelled from the ovary, fimbriae create fluid currents that act to carry the oocyte into the fallopian tube. Oocyte is carried toward the uterus by combination of tube peristalsis and cilia, which propel

the oocyte forward. The most desirable place for fertilization is the fallopian tube ***(Marieb and Katja, 2006).***

Ovaries:

- **Functions:** The ovaries are for oogenesis- production of eggs- and for hormone production.
- **Location and gross anatomy:** The ovaries are about the size and shape of almonds. They lie against the lateral walls of the pelvis, one on each side. They are enclosed and held in place by the broad ligament. As the developing egg begins to ripen or mature, follicle enlarges and develops a fluid filled central region. When the egg is matured, it is called a graafian follicle, and is ready to be ejected from the ovary ***(Marieb and Katja, 2006)***

Blood supply:

From the uterine and ovarian arteries, mostly the former. The uterine artery is a branch of the internal iliac artery. It runs in the lower edge of the broad ligament to the junction of the uterine body and cervix before running up the side of the uterus giving off several branches into the myometrium. The ureter lies immediately beneath the uterine artery ***(Marieb and Katja, 2006).***

MR imaging anatomy of female genital system

Since magnetic resonance imaging (MRI) offers high contrast resolution, provides good tissue characterization, and is capable of multi-planar imaging capabilities. Sagittal and coronal images are obtained along the long axis of the uterus and axial images perpendicular to coronal plane; it is becoming a useful tool for the evaluation of female pelvic pathology ***(Rayan et al., 2005)***

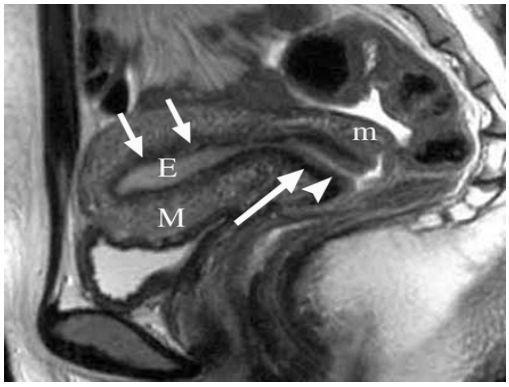

Fig. (2): Normal uterus in a woman of reproductive age. Sagittal T2-weighted image of the uterus shows the endometrium (E), junctional zone (short arrows), and myometrium (M). It also shows the epithelium (arrowhead), fibrous stroma (long arrow), and peripheral myomtrium (m) of the cervix ***(Quoted from Izumi et al., 2003).***

Female genital anatomy is best displayed on T2-weighted images. The Sagittal plane is the best to demonstrate uterine zonal anatomy (Fig 2):

- *The endometrium* has high signal intensity. The widths of the endometrium vary during the menstrual cycle (Fig 3); in the follicular phase it is typically 1-3 mm, endometrial width is widest and most clearly visible in the late secretory phase reaching up to 10 mm.

- *The junctional zone*, which corresponds to the innermost myometrium, appears as a band of low signal intensity.

The junctional zone may not be visible in premenarchal girls and postmenopausal women (fig 4). It differs from remainder of myomtrium as it had a shorter T1 and T2 with lower water content.

- *The peripheral myometrium* has intermediate signal intensity that is higher than that of the striated muscle. The myometrial signal intensity varies during menstrual cycle and is maximal during the secretory phase (Fig 3). Myometrial arcuate vessels are visible during the mid-secretory phase.

The uterine corpus is larger than the cervix throughout the reproductive-age period. In general, the corpus measures 6–8 cm in length by 5–6 cm in the transverse and anteroposterior dimensions ***(Izumi et al., 2003).***

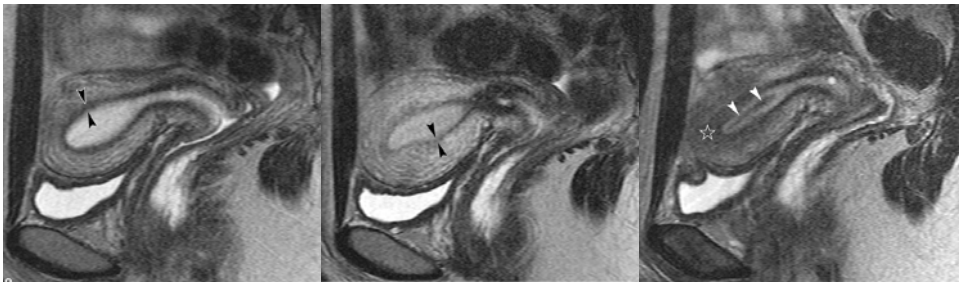

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Fig. (3): Uterine changes during the menstrual cycle in a 31-year-old woman. **(a)** Sagittal T2-weighted image obtained during the peri-ovulatory phase shows the anatomy of the three zones: endometrium, junctional zone (arrowheads), and outer myometrium. **(b)** Sagittal T2-weighted image obtained during the midsecretory phase shows increased thickness of the endometrium and myometrium. The signal intensity of the outer myometrium is increased. The thickness of the junction zone (arrowheads) is significantly decreased. **(c)** Sagittal T2-weighted image obtained during the menstrual phase shows that the uterine corpus appears smaller than during the periovulatory and midsecretory phases. The zonal anatomy of the myometrium is ill defined and irregularly thick (☆). The low-signal-intensity band in the middle of the endometrium (arrowheads) represents menstrual blood ***(Quoted from Kido et al., 2003)*.**

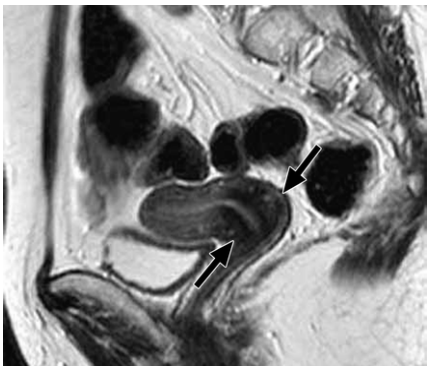

Fig. (4): Postmenopausal uterus. Sagittal T2-weighted image shows a small uterine corpus that is almost the same size as the cervix (arrows). The zonal anatomy of the corpus is indistinct ***(Quoted from Izumi et al., 2003).***

The cervix also shows zonal architecture on T2-weighted images. The central area of high signal intensity represents epithelium and mucus, the middle area of low signal intensity represents fibrous stroma, and the outer area of medium signal intensity represents peripheral myometrium. The vaginal wall has low signal intensity on T2-weighted images ***(Izumi et al., 2003)***.

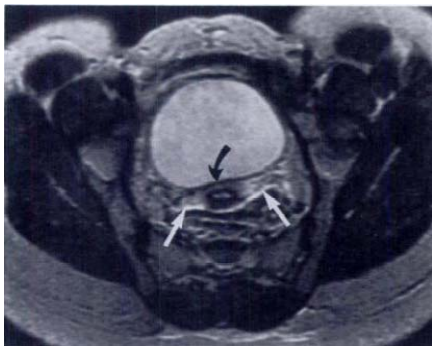

Fig. (5): Normal cervix and parametria. Axial oblique T2-weighted MR image obtained through the cervix (black arrow) demonstrates triangular moderate signal intensity of normal parametria (white arrows) ***(Quoted from Olson et al., 1992)*.**

The texture of ***the ovaries*** is clearly imaged in women of reproductive age; the normal ovary has a zonal anatomy consisting of an outer ovarian cortex and central ovarian medulla that along with the follicles compose the internal contents of the ovary. At histological examination, ovarian stroma in the cortex is more cellular, while medullary stroma is composed of looser, vascularized connective tissue with a higher free water content, thus explaining the difference in contrast on T2-weighted images ***(Siegelman and Outwater, 1999).***

Normal ***fallopian tubes*** are not routinely imaged because of their small diameter and tortuous course ***(Izumi et al., 2003).***

On T1-weighted images the uterus and ovaries are of homogenously intermediate signal intensity with poor intrinsic contrast, but the ligamentous structures are very well seen, being of low signal intensity compared to the surrounding fat. Also, muscles of the pelvic floor and sidewall are very well seen ***(Rayan et al., 2005).***

The peritoneal reflection of the broad ligament and pelvic floor is best seen on coronal images, outlined inferiorly by extra peritoneal fat. Imaging in the coronal plane allows evaluation of the lymphatic drainage along the internal and common iliac chains ***(Izumi et al., 2003).***

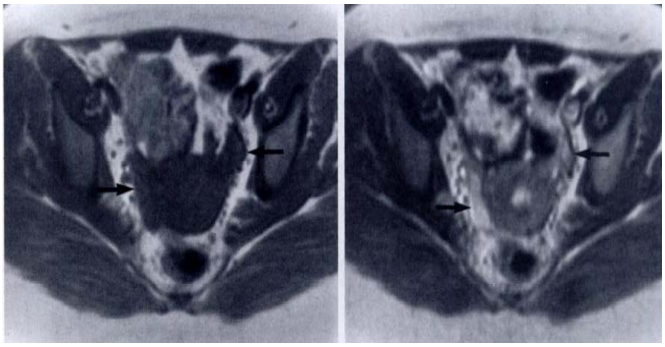

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Fig. (6): Normal ovaries in a patient of reproductive age. Axial T1-weighted (a) and T2-weighted (b) MR images demonstrate normal ovaries (arrows**) (*Quoted from Olson et al., 1992).***

T1-weighted imaging is performed in at least one plane, typically axial, to assess for adenopathy and again

with fat saturation to look for endometriosis or hemorrhagic cysts, which are bright on these images. The fat saturation images can also demonstrate fat in dermoid tumours ***(McRobbie et al., 2006).***

Tissue Characterization in the Female Pelvis by Means of MR Imaging

Pelvic imaging techniques such as computed tomography and ultrasonography provide a limited capability for tissue characterization. Fat, fluid, and calcification, for example, can be identified on the basis of parameters such as x-ray attenuation, echogenicity, and sound attenuation. Because of the many tissue parameters, such as T1, T2, magnetic susceptibility, and chemical shift, that contribute to signal intensity, magnetic resonance (MR) imaging may afford an ability to identify a wider array of specific tissues.

Lipid, fluid, hemorrhage, smooth muscle, fibrosis, solid malignant tissue, and hydrated soft tissue (including edema, mucin, and myxomatous tissue) have typical MR imaging properties (Table 1), and their presence in a mass can often be established on MR images. Consideration of the tissue composition of various pathologic processes in the pelvis can result in more systematic approaches to image interpretation and thus narrow the differential diagnosis ***(Siegelman and Outwater, 1999).***

Table (1): Summary of MR Characteristics of Pelvic Soft Tissues ***(Siegelman and Outwater, 1999).***

Tissue	T1 Signal Intensity*	T2 Signal Intensity*	Enhancement	Examples Where Tissue May Be Present
Fat	High†	Intermediate‡	None	Mature teratoma, lipoma, normal pelvic fat
Non-complicated fluid	Low	High§	None	Urine, spinal fluid, serous ascites, ovarian follicles
Blood				
Methemoglobin	Very high	Very low or high‖	None	Subacute hematomas, ectopic pregnancy, endometriomas, ovarian torsion
Ferritin or hemosiderin	Low	Very low	None	In the rim of maturing hematomas and endometriomas
Fibrous tissue or smooth muscle	Isointense	Low	Variable	Leiomyomas, adenomyosis, scar, solid endometriosis, ovarian fibroma, and Brenner tumor
Mucin	Low to high#	High	Peripheral with or without lacelike	Mucinous cystic ovarian neoplasms, pseudomyxoma peritonei, other mucinous adenocarcinomas
Myxomatous tissue	Low to isointense	High	Present but variable	Aggressive angiomyxoma, myxoid degeneration of a leiomyoma
Solid malignant tissue	Isointense	Isointense	Present	Endometrial, cervical, and ovarian carcinoma
* Signal intensity relative to that of the outer myometrium.				
† Lower signal intensity on fat-suppressed T1-weighted images and/or opposed-phase T1-weighted GRE images (see text for details).				
‡ Higher on fast SE images than on conventional T2-weighted images.				
§ Persistently high signal intensity on heavily T2-weighted images (MR hydrography).				
‖ Very low = intracellular methemoglobin; high = extracellular methemoglobin.				
# There is variable T1 shortening, which depends on the amount of hydration of the mucinous tissue.				

MAGNETIC RESONANCE IMAGING TECHNIQUE IN FEMALE PELVIS EXAMINATION

MR imaging provides clear delineation of internal and external uterine anatomy in multiple imaging planes, although it is not able to assess tubal patency or subtle, peritubal adhesion. The excellent tissue contrast of MR imaging allows specific diagnosis of many gynecological diseases ***(Rayan et al., 2005).***

The contraindications of MRI examination:

Before making an appointment, the physician should ask the patient if any absolute contraindication to MRI is present, these include:

- Cardiac pacemaker clips
- Cochlear implants and certain metallic objects ***(Kanal et al., 2007).***

Patient considerations:

No special patient preparation is necessary for pelvic MRI in most cases, unless otherwise stated.

When making an appointment for pelvic MRI:

- The patient should be informed about the most important aspects of an MR examination.