REVIEW ARTICLE

Transvaginal Color Doppler Sonography in the Evaluation of Normal Menstural Cycle

Irfan Robbani*, Geetanjali Gupta*, Tariq Ahmed Bhat**

The incorporation of color Doppler systems on transvaginal probes has made it possible to evaluate the normally occurring cyclical haemodynamic changes in the female pelvis. In addition to the depiction of major vascular channels, small intraparenchymal vessels within the uterus and ovaries can be easily demonstrated. While color flow imaging improves the ability to demonstrate vascular structures, spectral Doppler remains essential to define flow characteristics and vascular impedances in individual organs.

This article describes the sequential haemodynamic changes of the female pelvis, as depicted by transvaginal color Doppler imaging, during various phases of the menstrual cycle.

Applied Anatomy

The uterus and ovaries undergo sequential morphologic and functional changes throughout the life, starting at the embryonic stage and continuing till menopause, and beyond.

The ovaries are the only organs in the peritoneal cavity that are not invested by the peritoneum. The ovarian stroma consists of an inner medulla and an outer cortex, in which are embedded the ovarian follicles. The uterine wall is composed from without inwards of the perimetrium, the myometrium and the endometrium. The endometrium in turn is composed of two layers: the functional layer and the basalis layer. The functional layer that consists of a stratum compactum and stratum spongiosum, thickens in each cycle before it is shed with each menses. The basalis layer remains intact all through the cycle; it contains blood vessels that elongate to supply the functional endometrium, as and when it forms.

The anatomical layout of the pelvic vascular system is usually constant, except for some variations in the vessel size and flow, depending upon previous surgical interventions and the degree of parity. The uterine artery, which is an anterior branch of the internal iliac artery, divides at the cervicocorporeal junction into a descending and an ascending branch. While the descending branch is directed towards the upper cervix and the vagina, the ascending branch moves upwards, along the lateral aspect of the uterus towards the cornua, where it gives off an adnexal branch to supply the ovary. The uterine arteries of the two sides enter into an extensive anastomotic system with each other through the arcuate vessels of the myometrium. The endometrium is supplied by multiple radial arteries, which are better seen in the gravid uterus. The ovary has a dual blood supply; one from the adnexal branch of the uterine artery and the other from the ovarian artery, which originates from the abdominal aorta and reaches to supply the ovaries through the infundibulopelvic ligament.

Color Doppler Examination

Doppler sonography is based on the Doppler effect, which describes changes in the frequency of ultrasound

From the Departments of *Radio Diagnosis & Imaging and **General Medicine SKIMS, Soura (J&K) India.
Correspondence to : Dr. Irfan Robbani P. O. Box. 255, G.P.O. Srinagar, J&K, India.

scattered by the moving blood cells within a vessel. On color flow imaging, the color display is dependent upon the direction of blood flow relative to the transducer; conventionally red indicates flow towards the probe and blue indicates flow away from it. The level of color brightness is proportional to the blood flow velocity. The superimposition of such color flow data on the B-mode image provides an easy method for identification of vessels. The sample volume is chosen and the spectral waveforms are obtained from the region of interest. Various calculations and analyses are performed from the waveforms; modern sonography machines are provided with internal software to perform such measurements. Spectral waveform recordings should be considered satisfactory for such measurements only when at least five equally intense wave forms have been obtained in a row. The work of Taylor and coworkers (1) in 1985 addressed the possible use of Doppler sonography to evaluate the blood flow changes in the ovarian and uterine arteries during the physiologic phases of menstrual cycle. Since then, rapid advances in technology including the availability of transvaginal color flow imaging, have greatly enhanced our ability to perform haemodynamic assessments in the pelvic circulation.

Ovarian Haemodynamics

On color flow endosonography, the best quantitative information is obtained from interrogating the ovarian artery as it traverses the infundibulopelvic ligament to supply the ovary. However, care should be taken not to sample the internal iliac or hypogastric arteries, which lie adjacent to the lateral ovarian border and exhibit a distinct spectral wave pattern. Unfortunately, sampling the artery at the infundibulopelvic ligament may be difficult, partly because the ovarian arteries are of a smaller caliber and partly because they traverse the ligament at approximately 90^0 to the insinuating vaginal ultrasound beam (2). Kurjak and coworkers (2) were unsuccessful in obtaining color flow pattern and wave forms from ovarian arteries on vaginal Doppler; however they could obtain clear signals by a sensitive transabdominal Doppler. This is possibly because full urinary bladder displaces the bowel loops outside the pelvis, thereby permitting easier penetration of the Doppler signals. Other workers who differ from this observation have reported their success in obtaining spectral waveforms from the ovarian arteries by endovaginal pulsed Doppler, though, visualization of the arteries per se, was difficult (3). Doppler signals can also be obtained from the intraovarian vessels, especially during the postovulatory phase. It should be noted that the impedance to flow within the ovarian substance is lower as compared to the ovarian artery before it branches off into the ovary.

The ovarian haemodynamics is regulated by a combination of circulating hormonal levels and the side of the dominant follicle. During the early follicular phase, the spectral wave forms from the ovarian artery reveal high impedance pattern, with low amplitude waves and little or no diastolic flow. During the later part of follicular phase, when the dominant follicle is selected, the vascular resistance in the ipsilateral ovary begins to decrease. The waveforms now show a constant diastolic flow throughout the cardiac cycle, accompanied by an increase in the wave amplitude (Fig 1). The pulsatility index (P.I) consequently records a decrease. This low resistance flow continues throughout the periovulatory period remaining at this level for about 4 to 5 days. It is

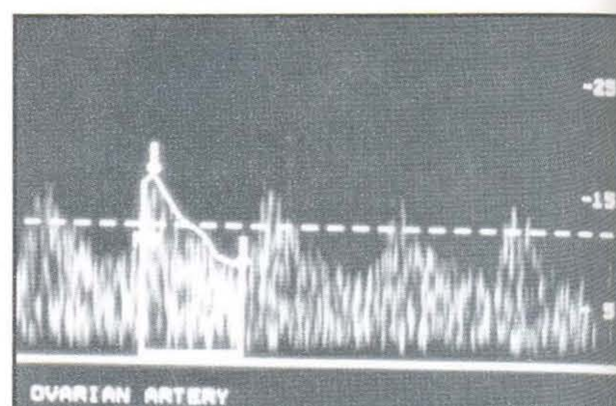

Fig 1. Waveforms obtained from the ovarian artery in the late follicular phase showing a constant diastolic flow.

thought that the drop in vascular resistance is secondary to hormone mediated changes in the vessel compliance (4,5). Since these changes begin in the immediate preovulatory period, they are thought to be initiated by factors other than progestrone, a known smooth muscle relaxant. Gradually, the vascular resistance starts increasing, till it reverts to the original high impedance state during the menstrual period. It is important to note that the non-dominant contralateral ovary maintains its high resistance pattern throughout the cycle.

One study found the resistance index (R.I) to be approximately 0.54 + 0.04 until ovulation approaches. About 2 days before ovulation the R.I. declined and reached its low of 0.44 + 0.04. It remained at this level for around 4-5 days and then gradually increased to 0.50 + 0.04 (6). In our experience with the evaluation of 25 subjects with normal menstrual cycles, the P.I. in the immediate pre-ovulatory phase was 0.80 + 0.17 and R.I. stood at 0.53 + 0.09. However, such measurements in isolation are not of much value in identifying the dominant ovary, since the range of normal values of pulsatility and resistance indices show wide variation. The best pointer would be to compare the indices from both the ovarian arteries and determine the side of least resistance.

In a number of patients, it is difficult to identify the corpus luteum on gray scales. With the superimposition of color flow signals, a colored ring pattern can be visualized around the corpus luteum wall, reflecting the physiologic angiogenesis in the corpus luteum. This should not be confused with the color flow signals expected with ectopic pregnancy or ovarian malignancy.

Uterine Haemodynamics

In 1932, Markee (7) reported the vasodilatory effect of estrogens on the uterine artery of rabbits. Other workers obtained similar results on experimental animals (8,9). This led to the speculation that hormonal fluctuations in the normal human menstrual cycle would probably also lead to cyclical changes in the uterine artery haemodynamics. The recent identification of estrogen receptors in the walls of human uterine arteries is supportive of such a concept (10). These works have generated a lot of interest in the evaluation of physiologic changes in the uterine haemodynamics, by means of sequential Doppler measurements.

The uterine arteries can be optimally imaged when the uterus is scanned in a longitudinal plane, though, imaging in transverse plane is also possible. The probe is directed into vaginal fornix and the scanning angle is altered until predominantly blue pulsations from the ascending branch of the ipsilateral uterine artery are obtained along the lateral border of the uterus. A red component to the image can be seen in the non-pregnant state when the uterine artery is tortuous. The distinction between the artery and the vein can be made on the basis of pulsation and brightness of color flow. Spectral waveforms from the uterine artery should be obtained at a level just above and adjacent to the supravaginal portion of the cervix. Scanning higher up could result in inclusion of waveforms from the site of anastomosis between the uterine and the ovarian artery.

During the menstrual phase, the uterine arteries exhibit high impedance to blood flow and the spectral waveforms show little or no diastolic flow. As the cycle advances the serum estradiol levels start fluctuating, thereby, producing corresponding changes in the uterine perfusion. High estrogen levels are known to occur during the period of rapid follicular growth and the midluteal phase of the cycle, which is the probable time of implantation, should pregnancy supervene. During this time the flow velocity waveforms show a low resistance flow. Steer and coworkers (11) conducted a study involving 23 women married to azoospermic men in whom investigation for female cause of infertility had proved negative. They observed that the mean P.I. for early follicular phase was 3.8 + 0.9, for late follicular phase 3.0 + 0.8 and for the luteal phase 2.5 + 0.9. In our experience with the evaluation of 25 subjects with normal menstrual cycles, the mean P.I. in the immediate pre-ovulatory phase was 0.80 + 0.17 and mean R.I. stood at 0.53 + 0.09. It may however be noted, that such cyclic impedance changes may not be observed in multiparous subjects, who may show persistence of a vasodilatory effect as a result of previous pregnancies (12,13).

References

1. Taylor KJW, Burns PN, Wells PNT, Conway DI, Hull MR. Ultrasound Doppler flow studies of the ovarian and uterine arteries. *Br J Obstet Gynecol* 1985; 92: 240-46.
2. Kurjak A, Jurkovic D, Alfirevic Z, Zalud I. Transvaginal color Doppler imaging. *J Clin Ultrasound* 1990; 18: 227-34.
3. Baber RJ, McSweeney MB, Gill RW et al. Transvaginal pulsed Doppler ultrasound assessment of blood flow to the corpus luteum in IVF patients following embryo transfer. Br *J Obstet Gynaecol* 1988; 95: 1226-30.
4. Dillon EH, Taylor KJW. Doppler ultrasound in female pelvis in first trimester of pregnancy. *Clin Diag Ultrasound* 1990; 26: 93-117.
5. Scholtes MCW, Wladimiroff JW, van Rigen HJM, Hop WCJ. Uterine and ovarian flow velocity waveforms in the normal menstrual cycle: A transvaginal Doppler study. *Fertil Steril* 1989; 52: 981-85.
6. Kurjak A, Kupesic S, Schulman H, Zalud I. Transvaginal flow Doppler in the assessment of ovarian and uterine flow in infertile women. *Fertil Steril* 1991; 56: 870-73.
7. Markee JE. An analysis of the rhythmic vascular chan the uterus of the rabbit. *Am J Physiol* 1932; 100: 374.
8. Van Orden DE, Farley DB, Fastenow C, Brody MJ technique for monitoring blood flow changes with miniatu Doppler floe probes. *Am J Physiol* 1984; 245: 1005-09.
9. Resnik R, Killam AP, Battaglia FC, Makowski EL, Mes G. The stimulation of uterine blood flow by various estrog *Endocrinology* 1974; 94: 1192-96.
10. Perrot-aplanat M, Groyer-picart MT, Garcia E, Lorenz Milgrom E. Immunocytochemical demonstration of estro and progesterone receptors in muscle cells of uterine arte in rabbits and humans. *Endocrinology* 1988; 123: 1511-
11. Steer C, Campbell S, Pampiglione JS, Kingsland CR, Ma BA, Collins WP. Transvaginal color flow imaging of uterine arteries during ovarian and menstrual cycles. *Hum Reprod* 1990; 5: 391-95.
12. Goswamy RK, Steptoe PC. Doppler ultrasound studies the uterine artery in spontaneous ovarian cycles. *Hum Reprod* 1988; 3: 721-26.
13. Thaler I, Manor D, Rotten S, et al. Haemodynamic evaluatio of the female pelvic vessels using high-frequency transvagin image-directed Doppler system. *J Clin Ultrasound* 1990; 1 364-69.