Doppler Study of Uterine and Ovarian Arteries in Relation to Clinical and Laboratory Findings in Cases of Polycystic Ovarian Syndrome

Original Article

Sara Taha Mostafa[1], *Ayman Ahmed Abdelhamid Shedid*[1], *Walaa Mohammed Hassan Hassan*[2] *and Mohammed Abdelmaboud Elgazar*[1]

[1]*Department of Obstetrics and Gynecology, Faculty of Medicine, Benha University, Benha, Egypt*

[2]*Department of Obstetrics and Gynecology, Abu-Hammad Central Hospital, Al-Sharqia, Egypt*

ABSTRACT

Objectives: To conduct Doppler assessments of ovarian and uterine blood flow, comparing these findings with clinical and laboratory observations in women diagnosed with Polycystic Ovarian Syndrome (PCOS).

Study Design: A cross-sectional study.

Patients and Methods: This study was conducted involving 107 PCOS-diagnosed women. Clinical examinations, hormonal assays, and transvaginal Doppler assessments of ovarian and uterine arteries were performed. Correlations between body mass index (BMI), hormonal levels, hirsutism, menstrual irregularities, and Doppler indices were analyzed.

Results: The patients had an average age of 25.47 years, with a Body Mass Index (BMI) ranging from 22 to 36.4 kg/m². Significant correlations were noted between BMI and ovarian Doppler indices (Resistive Index (RI), Systolic to Diastolic (SD) ratio, and Pulsatility Index (PI)), as well as uterine artery Doppler measurements (RI, PI, and SD ratio). Hormonal levels showed significant correlations with uterine and ovarian sizes, with Luteinizing Hormone (LH) demonstrating positive correlations with uterine size and negative correlations with specific ovarian parameters.

Conclusion: The study showed significant correlations between BMI, hormonal levels, hirsutism, menstrual irregularities, and Doppler measurements of uterine and ovarian blood flow in PCOS patients.

Key Words: Doppler; hormonal correlations; ovarian arteries; PCOS; uterine arteries.

Received: 19 January 2024, **Accepted:** 09 February 2024

Corresponding Author: Walaa Mohammed Hassan Hassan, Department of Obstetrics and Gynecology, Abu-Hammad Central Hospital, Al-Sharqia, Egypt, **Tel.:** +2010 9911 5049, **E-mail:** warm.mohamed90@gmail.com

ISSN: 2090-7265, August 2024, Vol.14, No. 3

INTRODUCTION

Polycystic ovarian syndrome (PCOS) is a common endocrine disorder that predominantly impacts women of reproductive age. It involves a range of symptoms, including irregularities in ovulation, hyperandrogenism, insulin resistance, and disruptions in metabolic function. The development of PCOS may be linked to abnormalities in the metabolism of androgens and estrogens, along with dysregulation in the hypothalamic-pituitary-ovarian (HPO) axis[1].

The syndrome manifests diversely, commonly presenting with menstrual irregularities, indications of androgen excess (such as acne and hirsutism), insulin resistance, obesity, elevated LH levels, dyslipidemia, and an increased risk of conditions like type 2 diabetes and cardiovascular events[2].

The Rotterdam ESHRE/ASRM-sponsored PCOS consensus defines diagnostic criteria that require the presence of at least two of the following three criteria: oligo-ovulation/anovulation, clinical/biochemical signs of hyperandrogenism, and specific ovarian characteristics on ultrasonography[3].

Studies have debated the role of transvaginal Doppler ultrasound in assessing uterine and ovarian vascularity in PCOS, suggesting a correlation between blood flow patterns and organ function/morphology[4,5]. Early Doppler ultrasound studies have highlighted increased stromal vascularity in polycystic ovaries, with the follicular phase (days 3-5 of the menstrual cycle) considered optimal for ultrasonography in diagnosing PCOS[6].

Doppler ultrasound proves valuable as a non-invasive, readily available method with significant sensitivity in

DOI:10.21608/EBWHJ.2024.263964.1293

diagnosing PCOS[7,8]. Studies indicate variability in blood flow patterns in uterine and ovarian arteries among PCOS patients, particularly lower peak systolic and end-diastolic velocities compared to controls[9].

Ongoing exploration focuses on the relationship between Doppler ultrasonographic criteria and serum hormone tests. If these criteria align significantly, they could serve as supplementary diagnostic measures in settings where hormone tests are not accessible[10].

The purpose of this study was to conduct Doppler assessments of ovarian and uterine blood flow, comparing these findings with clinical and laboratory observations in women diagnosed with PCOS.

PATIENTS AND METHODS

Study design and population

From October 2022 to October 2023, a cross-sectional study took place in the Obstetrics and Gynecology departments at both Benha University Hospital and Abu-Hammad Central Hospital. Patients provided informed written consent, received a study explanation, and were assigned secret code numbers. Approval for the study was granted by the Research Ethics Committee at the Faculty of Medicine, Benha University.

The study's inclusion criteria involved women diagnosed with PCOS according to the Rotterdam criteria, requiring the presence of a minimum of two out of three specific criteria. These criteria included oligo-ovulation or anovulation, characterized by infrequent ovulation (cycles lasting over 35 days or fewer than eight cycles per year). Additionally, clinical or biochemical signs of hyperandrogenism, marked by an excessive presence of male sex hormones like testosterone, and confirmation of PCOS on ultrasonography were essential. PCOS on ultrasound was defined as one or both ovaries exhibiting 12 or more follicles measuring between 2-9mm in diameter, along with an ovarian volume exceeding 10 cm^3.

Conversely, exclusion criteria were established to ensure a specific cohort for analysis. Excluded were patients with conditions potentially impacting the circulatory system, including hypertension, diabetes mellitus, autoimmune diseases, cardiovascular diseases, anemia, Cushing syndrome, thyroid disease, and hyperprolactinemia. Also excluded were individuals on ovulation-inducing drugs, those with androgen-secreting tumors in the ovaries or adrenal glands, adult-onset congenital adrenal hyperplasia, follicular cysts larger than 20 mm in the early follicular phase, a history of tubal or ovarian surgery or pathology, pregnant women, and those using contraceptive pills.

Methods

All patients were subjected to the following:

Clinical Examination and History

All patients underwent a comprehensive assessment comprising detailed history-taking, including age, parity, hirsutism, and menstrual and obstetric history. Additionally, a general, abdominal, and pelvic examination was conducted to evaluate overall health and specific reproductive system conditions.

Assessment of Hirsutism and Laboratory Investigations

Hirsutism was assessed using the modified Ferriman-Gallwey score, which evaluates nine body areas for excessive hair growth. Laboratory investigations involved collecting serum and plasma samples between 8:00 and 10:00 AM, after an overnight fast during the early follicular phase, measuring FSH, LH, free Testosterone, and other pertinent tests for differential diagnosis of PCOS. Patients diagnosed with PCOS based on laboratory and clinical findings underwent further assessments.

Transvaginal Ultrasound with Doppler Assessment

Women meeting diagnostic criteria for PCOS underwent transvaginal ultrasound with Doppler assessment of uterine and ovarian arteries. Basic scans were conducted during the early follicular phase, evaluating ovarian parameters like antral follicular count, ovarian size, and stromal blood flow characteristics including RI, PI, and S/D ratio. Uterine size and uterine artery indices (RI, PI, S/D ratio) were also measured. The technique involved transvaginal Doppler flow measurements, visualizing blood vessels trans-vaginally, and performing color Doppler to assess vascularization. Various Doppler indices were obtained and calculated using specific formulas. Evaluations were standardized by conducting assessments at the same time of day to avoid circadian rhythm fluctuations. The apparatus used for these assessments was the GE Voluson 730 Pro/Expert CRT Monitor Model AY-15 CUK equipped with a 5-7.5MHz transvaginal transducer, maintaining uniform power Doppler ultrasound settings for consistency across all evaluations.

Statistical Analysis

The analysis of data utilized SPSS (Statistical Package for the Social Sciences) software, version 26 . Categorical variables were characterized by their absolute frequencies and compared using chi-square tests, Fisher exact tests, and Monte Carlo tests when appropriate. The chi-square for trend test was employed to compare ordinal data between two groups. The Shapiro-Wilk test verified assumptions for parametric tests. Quantitative variables were described by means and standard deviations or median and interquartile range, depending on the data type. Comparison of quantitative data between two groups involved the use of independent sample t-tests for normally distributed data. Pearson correlation coefficients were employed to assess the strength and direction of correlation between two continuous variables (for normally distributed data), while Spearman rank correlation coefficients were used for non-normally distributed data. The level of statistical significance was set at $P < 0.05$, with a highly significant difference indicated if $p \leq 0.001$.

RESULTS

This study comprised 107 participants aged between 18 and 35, with an average age of 25.47 years. The body mass index (BMI) ranged from 22 to 36.4 kg/m², with an average of 26.47 kg/m². Among the patients, 79.4% were infertile, 94.4% experienced menstrual irregularities, and 80.4% exhibited hirsutism. The Modified Ferryman score varied from 6 to 21, with a median of 9. The mean levels of LH, FSH, and free testosterone were 11.8, 6.09, and 4.94 IU/ml, respectively. The mean antral counts for the right and left ovaries were 15.21 and 15, resulting in an overall mean of 15.1. The average sizes for the right and left ovaries were 11.72 cm³ and 11.69 cm³, respectively, with a combined mean ovarian size of 11.71 cm³. The mean uterine size was 89.19 cm³ (Table 1).

A statistically significant negative correlation was observed between BMI and the right ovary's RI, as well as the SD ratio for both right and left ovaries. Conversely, a statistically significant positive correlation was found between BMI and the PI for the right, left, and mean ovaries. No significant correlations were observed between BMI and other ovarian Doppler data. Age showed statistically non-significant correlations with any ovarian Doppler data. In terms of uterine Doppler data, a statistically significant negative correlation was identified between BMI and the RI for both right and left uterine arteries, as well as the PI and SD ratio for right, left, and mean uterine arteries. However, there was a non-significant correlation between BMI and the right uterine artery's RI. Age exhibited statistically non-significant correlations with uterine Doppler data (Table 2).

LH demonstrated a significant positive correlation only with uterine size, while FSH showed significant positive correlations with uterine size and the sizes of the right, left, and mean ovaries. Free testosterone exhibited significant positive correlations with uterine size and the sizes of the right, left, and mean ovaries. LH displayed a significant negative correlation with various ovarian measurements, while FSH had a significant negative correlation with specific uterine measurements (Table 3).

A statistically significant relation was found between hirsutism and free testosterone levels, with higher levels associated with hirsutism. However, there was no significant relation between hirsutism and LH or FSH levels. Hirsutism showed a statistically significant relation with lower SD ratios in the right, left, and mean ovaries. No significant relations were observed between hirsutism and other ovarian Doppler parameters. In terms of uterine Doppler parameters, a statistically significant relation was found between hirsutism and higher RI values in the right, left, and mean uterine arteries. No significant relations were observed between hirsutism and other uterine Doppler parameters (Table 4).

Menstrual irregularities showed a statistically significant relation with higher LH, free testosterone, and FSH levels. Additionally, a significant relation was observed between menstrual irregularities and higher SD ratios in the right, left, and mean ovaries. No significant relations were observed between menstrual irregularities and other ovarian Doppler parameters. Regarding uterine Doppler parameters, a statistically significant relation was found between menstrual irregularities and higher RI values in both right and left uterine arteries. No significant relations were observed between menstrual irregularities and other uterine Doppler parameters (Table 5).

Table 1: Distribution of patients according to demographic data and clinical data:

	Mean ± SD	Range
Age (year)	25.47 ± 3.41	18 – 35
BMI (kg/m2)	26.47 ± 3.27	22 – 36.4
	N=107	%
Infertility	85	79.4%
Menstrual irregularities	101	94.4%
Hirsutism	86	80.4%
	Median (IQR)	Range
Modified-ferryman score	9 (8 – 11)	6 – 21
laboratory data	Mean ± SD	Range
LH (IU/ml)	11.8 ± 2.25	7.5 – 16.1
FSH (IU/ml)	6.09 ± 1.66	2.6 – 10.4
Free testosterone (IU/ml)	4.94 ± 1.57	1.9 – 7.8
Ultra-sonographic data		
Right antral count	15.21 ± 1.99	12 – 20
Left antral count	15.0 ± 2.42	10 – 21
Mean antral count	15.1 ± 2.0	11 – 20
Right ovarian size	11.72 ± 1.47	9.6 – 16
Left ovarian size	11.69 ± 1.47	9.8 – 16
Mean ovarian size	11.71 ± 1.46	9.7 – 16
Uterus size	89.19 ± 8.61	81.94 – 140.13
Doppler data		
Right ovary RI	0.52 ± 0.04	0.43 – 0.6
Left ovary RI	0.53 ± 0.04	0.44 – 0.61
Mean ovarian artery RI	0.53 ± 0.04	0.44 – 0.61
Right ovary PI	0.94 ± 0.19	0.8 – 1.8
Left ovary PI	0.93 ± 0.19	0.8 – 1.82
Mean ovarian artery PI	0.94 ± 0.19	0.8 – 1.81
Right ovary SD ratio	2.24 ± 1.03	0.61 – 5.1
Left ovary SD ratio	2.24 ± 1.03	0.61 – 5.12
Mean ovarian artery SD ratio	2.24 ± 1.03	0.61 – 5.11
Right uterine RI	0.93 ± 0.13	0.56 – 1.3
Left uterine RI	0.9 ± 0.14	0.56 – 1.
Mean uterine artery RI	0.92 ± 0.1	0.56 – 1.25
Mean uterine artery PI	3.34 ± 0.41	0.86 – 3.63
Right uterine PI	3.33 ± 0.41	0.86 – 3.62
Left uterine PI	3.33 ± 0.42	0.86 – 3.63
Right uterine SD ratio	7.02 ± 1.66	2.28 – 9.53
Left uterine SD ratio	7.04 ± 1.67	2.26 – 9.95
Mean uterine artery SD ratio	7.03 ± 1.66	2.27 – 9.53

SD: Standard Deviation, BMI: Body Mass Index, LH: Luteinizing Hormone, FSH: Follicle-Stimulating Hormone, IU: International Units, IQR: Interquartile Range, RI: Resistive Index, PI: Pulsatility Index.

Table 2: Correlation between age, BMI and ovarian and Uterine Doppler data of studied patients:

	Age (year)		BMI (kg/m²)	
	r	*p*	r	*p*
Right ovary RI	0.153	0.11	-0.255	0.008*
Left ovary RI	0.0	0.68	-0.073	0.453
Mean ovarian artery RI	0.109	0.266	-0.184	0.058
Right ovary PI	0.087	0.375	0.249	0.01*
Left ovary PI	0.086	0.376	0.255	0.008*
Mean ovarian artery PI	0.087	0.375	0.252	0.009*
Right ovary SD ratio	0.107	0.274	-0.328	0.001**
Left ovary SD ratio	0.107	0.272	-0.33	0.001**
Mean ovarian artery SD ratio	0.107	0.273	-0.329	0.001**
	Age (year)		BMI (kg/m²)	
	r	*p*	r	*p*
Right uterine RI	0.021	0.833	-0.184	0.058
Left uterine RI	-0.002	0.984	-0.319	0.001**
Mean uterine artery RI	0.009	0.926	-0.271	0.005*
Mean uterine artery PI	-0.091	0.35	-0.403	**0.001>
Right uterine PI	-0.106	0.278	-0.399	<0.001**
Left uterine PI	-0.099	0.312	-0.401	<0.001**
Right uterine SD ratio	-0.094	0.338	-0.235	0.015*
Left uterine SD ratio	-0.087	0.373	-0.225	0.02*
Mean uterine artery SD ratio	-0.09	0.355	-0.23	0017*

r Pearson correlation coefficient *$p<0.05$ is statistically significant **$p\leq0.001$ is statistically highly significant.

Table 3: Correlation between LH, FSH, free testosterone and ultra-sonographic, and ovarian and uterine Doppler data of studied patients' data:

Ultra-sonographic data	LH		FSH		Free testosterone	
	r	p	r	p	r	*p*
Right antral count	0.063	0.521	-0.053	0.591	-0.059	0.549
Left antral count	0.069	0.477	0.041	0.672	-0.072	0.463
Mean antral count	0.073	0.454	-0.001	0.991	-0.072	0.469
Right ovarian size	0.155	0.111	0.34	<0.001**	0.255	0.008*
Left ovarian size	0.164	0.092	0.372	<0.001**	0.273	0.004*
Mean ovarian size	0.16	0.101	0.356	<0.001**	0.264	0.006*
Uterus size	0.196	0.043*	0.204	0.035*	0.209	0.03*
Ovarian Doppler data						
Right ovary RI	-0.223	0.021*	-0.117	0.228	-0.044	0.652
Left ovary RI	-0.032	0.743	-0.024	0.809	0.024	0.804
Mean ovarian artery RI	-0.144	0.138	-0.08	0.415	-0.013	0.892
Right ovary PI	-0.176	0.07	0.1	0.305	-0.114	0.242
Left ovary PI	-0.175	0.071	0.098	0.315	-0.106	0.275
Mean ovarian artery PI	-0.176	0.071	0.099	0.31	-0.11	0.258
Right ovary SD ratio	-0.263	0.006*	-0.085	0.385	-0.045	0.642
Left ovary SD ratio	-0.27	0.005*	-0.086	0.38	-0.047	0.632
Mean ovarian artery SD ratio	-0.267	0.005*	-0.085	0.385	-0.046	0.637
Uterine Doppler data						
Right uterine RI	0.186	0.055	-0.128	0.188	0.304	0.001**
Left uterine RI	-0.079	0.419	-0.205	0.034*	0.154	0.113
Mean uterine artery RI	0.047	0.631	-0.071	0.466	0.237	0.014*
Mean uterine artery PI	0.018	0.561	-0.073	0.454	0.005	0.957
Right uterine PI	0.017	0.862	-0.071	0.466	0.005	0.96
Left uterine PI	0.02	0.841	-0.072	0.46	0.006	0.954
Right uterine SD ratio	-0.012	0.899	-0.211	0.029*	-0.018	0.951
Left uterine SD ratio	-0.033	0.739	-0.206	0.033*	-0.009	0.924
Mean uterine artery SD ratio	-0.023	0.818	-0.209	0031*	-0.014	0.887

r Pearson correlation coefficient **p*<0.05 is statistically significant **p≤0.001 is statistically highly significant.

Table 4: Relation between hirsutism and serum LH, FSH, free testosterone among studied patients and relation between hirsutism and ovarian and uterine Doppler among studied patients:

	Hirsutism N=86	No hirsutism N=21	t	*p*
	Mean ± SD	Mean ± SD		
LH	11.91 ± 2.31	11.36 ± 1.98	1.018	0.311
FSH	6.19 ± 1.69	5.48 ± 1.47	1.353	0.179
Free testosterone	5.44 ± 1.21	2.9 ± 1.2	8.629	<0.001**
Ovarian Doppler				
Right ovary RI	0.52 ± 0.05	0.52 ± 0.04	-0.213	0.832
Left ovary RI	0.53 ± 0.04	0.53 ± 0.4	0.63	0.53
Mean ovarian artery RI	0.53 ± 0.04	0.53 ± 0.04	0.191	0.849
Right ovary PI	0.92 ± 0.15	1.0 ± 0.28	-1.245	0.226
Left ovary PI	0.92 ± 0.16	1.0 ± 0.28	-1.205	0.241
Mean ovarian artery PI	0.92 ± 0.16	1.0 ± 0.28	-1.225	0.233
Right ovary SD ratio	2.12 ± 1.07	2.7 ± 0.69	-3.049	0.004*
Left ovary SD ratio	2.12 ± 1.07	2.71 ± 0.69	-3.078	0.003*
Mean ovarian artery SD ratio	2.12 ± 1.07	2.7 ± 0.69	-3.064	0.004*
Uterine Doppler				
Right uterine RI	0.95 ± 0.14	0.88 ± 0.03	3.992	<0.001**
Left uterine RI	0.91 ± 0.16	0.87 ± 0.07	2.099	0.039*
Mean uterine artery RI	0.93 ± 0.14	0.88 ± 0.05	3.074	0.003*
Mean uterine artery PI	3.33 ± 0.44	3.36 ± 0.24	-0.366	0.715
Right uterine PI	3.33 ± 0.45	3.37 ± 0.24	-0.357	0.722
Left uterine PI	3.33 ± 0.45	3.37 ± 0.24	-0.375	0.708
Right uterine SD ratio	7.08 ± 1.69	6.75 ± 1.54	0.817	0.416
Left uterine SD ratio	7.11 ± 1.7	6.75 ± 1.54	0.874	0.384
Mean uterine artery SD ratio	7.1 ± 1.69	6.75 ± 1.54	0.847	0.399

*$p<0.05$ is statistically significant **$p\leq0.001$ is statistically highly significant t independent sample t test.

Table 5: Relation between menstrual irregularities and hormonal profile, ovarian and uterine Doppler among studied patients:

Mean ± SD	Menstrual irregularities N=101	No Menstrual irregularities N=6	t	p
	Mean ± SD			
LH	14.43 ± 1.48	11.65 ± 2.19	4.348	0.001**
FSH	6.88 ± 1.64	6.04 ± 1.66	5.913	<0.001**
Free testosterone	6.18 ± 1.67	4.73 ± 0.5	2.113	0.037*
Right ovary RI	0.52 ± 0.04	0.48 ± 0.05	2.205	0.03*
Left ovary RI	0.53 ± 0.04	0.49 ± 0.5	2.852	0.005*
Mean ovarian artery RI	0.53 ± 0.04	0.48 ± 0.05	2.976	0.004*
Right ovary PI	0.93 ± 0.17	1.02 ± 0.38	-0.577	0.588
Left ovary PI	0.93 ± 0.17	1.02 ± 0.39	-0.577	0.588
Mean ovarian artery PI	0.93 ± 0.17	1.02 ± 0.39	-0.577	0.588
Right ovary SD ratio	2.27 ± 1.04	1.65 ± 0.73	1.422	0.203
Left ovary SD ratio	2.27 ± 1.03	1.66 ± 0.75	1.428	0.156
Mean ovarian artery SD ratio	2.27 ± 1.04	1.65 ± 0.74	0.12	0.904
Right uterine RI	0.94 ± 0.12	0.89 ± 0.19	3.992	<0.001**
Left uterine RI	0.91 ± 0.14	0.83 ± 0.14	2.099	0.039*
Mean uterine artery RI	0.93 ± 0.14	0.88 ± 0.05	1.238	0.218
Mean uterine artery PI	3.34 ± 0.39	3.18 ± 0.66	0.999	0.32
Right uterine PI	3.33 ± 0.45	3.37 ± 0.24	-0.357	0.722
Left uterine PI	3.35 ± 0.4	3.17 ± 0.67	-0.375	0.708
Right uterine SD ratio	7.02 ± 1.69	6.97 ± 1.09	0.81	0.416
Left uterine SD ratio	7.05 ± 1.7	6.93 ± 1.04	0.874	0.384
Mean uterine artery SD ratio	7.1 ± 1.69	6.75 ± 1.54	0.12	0.904

*$p<0.05$ is statistically significant **$p\leq0.001$ is statistically highly significant t independent sample t test.

DISCUSSION

This cross-sectional study aimed to assess Doppler-assessed ovarian and uterine blood flow and its correlation with clinical and laboratory findings in 107 PCOS patients (mean age: 25.47 years, mean BMI: 26.47 kg/m²). The majority of patients exhibited infertility (79.4%), menstrual irregularities (94.4%), and hirsutism (80.4%). Laboratory results indicated mean levels of LH (11.8 IU/ml), FSH (6.09 IU/ml), and free testosterone (4.94 IU/ml). Transvaginal ultrasound with Doppler assessments was used to examine ovarian and uterine arteries. Statistical analysis revealed significant correlations between BMI and various Doppler parameters, including a negative correlation with specific ovarian and uterine artery resistance and pulsatility measures, and a positive correlation with certain ovarian pulsatility measures. No significant correlation was found between age and any Doppler parameters for either ovarian or uterine arteries.

These findings align with a recent study concluded that Doppler indices could correlate with overweight in PCOS cases. They reported a statistically significant negative correlation between BMI and Uterine artery PI and ovarian artery RI[9]. Another study found no correlation between BMI, age, and ovarian/uterine Doppler data (RI of the uterine artery and ovarian stromal RI)[11].

Regarding the correlation of laboratory results with ultrasonographic findings in our study, there were statistically significant positive correlations. LH showed a significant positive correlation with uterine size. FSH exhibited significant positive correlations with uterine size, right, left, and mean ovarian sizes. Free testosterone also showed significant positive correlations with uterine size, right, left, and mean ovarian size.

In agreement with our study, a recent study[12] reported a significant relationship between ovarian volume, quantified by ultrasonographic measurements, and increasing serum levels of free testosterone. Similarly, a study demonstrated a significant correlation between mean ovarian volume and LH and free testosterone[11].

In correlating laboratory findings with ovarian Doppler data, a statistically significant negative correlation emerged between LH and all of the right ovary RI, right, left, and mean ovary SD. Conversely, there was a non-significant correlation between LH and other ovarian Doppler parameters. There were no statistically significant correlations between FSH or free testosterone and any of the ovarian Doppler data.

These findings align with a recent study[6] reported an inverse correlation between luteinizing hormone (LH) and ovarian artery RI (r=−0.25; P=0.007) in PCOS patients. However, their study differed from ours in the correlation between testosterone and PI (r=−0.30; *P*<0.0001) and RI (r=−0.48; *P*<0.0001) in women with PCOS. A study also found no association between Doppler indices and hormonal factors[11].

In our investigation concerning the association between LH, FSH, free testosterone, and uterine Doppler data among the participants, we observed no statistically significant correlation between LH and any uterine Doppler parameters. However, a statistically significant negative correlation was found between FSH and the RI of the left uterine artery, as well as the SD of the right, left, and mean uterine arteries. Conversely, a non-significant correlation was noted between FSH and other uterine artery Doppler parameters. Additionally, a statistically significant negative correlation emerged between free testosterone and the RI of the right and mean uterine arteries, while showing a non-significant correlation with other uterine artery Doppler parameters. These results align with a previous study that also reported an insignificant correlation between LH and uterine artery Doppler indices in PCOS patients[13].

When correlating clinical findings with laboratory results in our study, we found a statistically significant relationship between hirsutism and free testosterone levels, which were higher in patients with hirsutism. However, there was no statistically significant relationship between hirsutism and either LH or FSH. Our findings mirrored those of a study reported a significant positive correlation between free testosterone levels and the degree of hirsutism[14].

Regarding menstrual irregularities, our study found a statistically significant relationship between LH, FSH, free testosterone levels, and the presence of menstrual irregularities, which were higher in patients experiencing menstrual irregularities. A recent study similarly reported that the higher the degree of menstrual irregularity, the higher the levels of luteinizing hormone, follicle-stimulating hormone, and testosterone[15].

Upon examining the correlation of clinical findings with ovarian and uterine artery Doppler indices, we identified a statistically significant association between hirsutism and the lower right, left, and mean ovarian SD ratios in patients with hirsutism. Nevertheless, no statistically significant relationship was observed between hirsutism and other ovarian Doppler parameters. Moreover, a statistically significant relationship was noted between hirsutism and the higher right, left, and mean uterine resistance indices (RI), specifically in patients with hirsutism. However, no statistically significant association was found between hirsutism and other uterine Doppler parameters.

Similarly, we found a statistically significant relationship between menstrual irregularities and the right, left, and mean ovarian SD ratio, which were higher in patients with menstrual irregularities. However, there was no statistically significant relationship between menstrual irregularities and other ovarian Doppler parameters. Moreover, a statistically significant relationship existed between menstrual irregularities and both right and left uterine RI, which were higher in patients with menstrual irregularities. Yet, there was no statistically significant relationship between menstrual irregularities and other uterine Doppler parameters. These results aligned with a study reported significant correlations between Doppler indices and markers of ovarian dysfunction[6].

CONCLUSIONS

The study revealed significant negative correlations between LH and various ovarian Doppler parameters, including right ovary RI, and mean ovary SD, as well as significant negative correlations between FSH and left uterine artery RI, right, left, and mean uterine SD. Additionally, free testosterone showed significant negative correlations with right and mean uterine artery RI. Notably, hirsutism exhibited significant relations with right, left, and mean ovarian SD ratio, while menstrual irregularities were significantly related to both right and left uterine RI. These findings suggest that Doppler ultrasonographic criteria display meaningful associations with clinical manifestations and serum hormone tests in PCOS patients, potentially serving as a valuable adjunct diagnostic tool where conventional tests are unavailable.

CONFLICT OF INTERESTS

There are no conflicts of interest.

REFERENCES

1. Witchel SF, Oberfield SE, Peña AS. Polycystic Ovary Syndrome: Pathophysiology, Presentation, and Treatment With Emphasis on Adolescent Girls. J Endocr Soc. 2019 Aug 1;3(8):1545-1573.

2. Louwers YV, Laven JSE. Characteristics of polycystic ovary syndrome throughout life. Ther Adv Reprod Health. 2020 Jan-Dec;14:2633494120911038.

3. Christ JP, Cedars MI. Current Guidelines for Diagnosing PCOS. Diagnostics (Basel). 2023 Mar 15;13(6).

4. Garg N, Khaira HK, Kaur M, *et al*. A Comparative Study on Quantitative Assessment of Blood Flow and Vascularization in Polycystic Ovary Syndrome Patients and Normal Women Using Three-Dimensional Power Doppler Ultrasonography. J Obstet Gynaecol India. 2018 Apr;68(2):136-141.

5. Pan HA, Wu MH, Cheng YC, *et al*. Quantification of Doppler signal in polycystic ovary syndrome using three-dimensional power Doppler ultrasonography: a possible new marker for diagnosis. Hum Reprod. 2002 Jan;17(1):201-6.

6. Wang WQ, Chu GH, Hou XX. A comparison of Doppler measures of ovarian blood flow between women with and without ovarian dysfunction and correlations of Doppler indices with ovarian dysfunction markers: a meta-analysis. Ann Transl Med. 2023 Jan 31;11(2):110.

7. Gyliene A, Straksyte V, Zaboriene I. Value of ultrasonography parameters in diagnosing polycystic ovary syndrome. Open Med (Wars). 2022;17(1):1114-1122.

8. Christ JP, Cedars MI. Current Guidelines for Diagnosing PCOS. Diagnostics. 2023;13(6):1113.

9. Saleh Abukraa ZA, Sarhan A-MM, Abdelhady RR, *et al*. Correlation between doppler indices, clinical and laboratory findings in cases of polycystic ovarian syndrome. Zagazig University Medical Journal. 2020;26(6):962-969.

10. Yu HK, Liu X, Chen JK, *et al*. Pelvic Ultrasound in Diagnosing and Evaluating the Efficacy of Gonadotropin-Releasing Hormone Agonist Therapy in Girls With Idiopathic Central Precocious Puberty. Front Pharmacol. 2019;10:104.

11. Younesi L, Safarpour Lima Z, Akbari Sene A, *et al*. Comparison of uterine and ovarian stromal blood flow in patients with polycystic ovarian syndrome. Endocr Connect. 2019 Jan 1;8(1):50-56.

12. Lee SY, Yu EH. Correlation of ovarian volume and clinical and laboratory parameters of PCOS in Korean patients. 2022.

13. Fetouh AA, Mohamed RS. Ovarian Doppler study in polycystic ovary syndrome in relation to body weight. AL-Azhar Assiut Med J. 2015;13:34-42.

14. Khan A, Karim N, Ainuddin JA, *et al*. Polycystic Ovarian Syndrome: Correlation between clinical hyperandrogenism, anthropometric, metabolic and endocrine parameters. Pak J Med Sci. 2019 Sep-Oct;35(5):1227-1232.

15. Hussein K, Karami M. Association between insulin resistance and abnormal menstrual cycle in Saudi females with polycystic ovary syndrome. Saudi Pharm J. 2023 Jun;31(6):1104-1108.