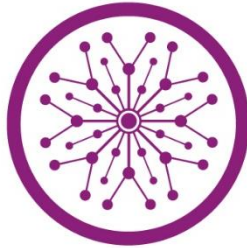


**Investigating the Relationship between Uterine and Ovarian Artery
Indices and Follicle in PCOS through Color Doppler**



SUPERIOR UNIVERSITY

Thesis Submitted to

The Superior University Lahore

In Partial Fulfillment of the

Requirement for the Degree of

Master of Science in Allied Health Sciences

By

ABRAR HABIB

SU91-MSAHW-F23-053

Session: 2023-2025

Faculty of Allied Health Sciences

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No part of this thesis has been submitted anywhere else for any other degree. This thesis is submitted to the Faculty of Allied Health Sciences, The Superior University, Lahore in partial fulfillment of the requirements for the degree of Master of Science in the field of **“Allied Health Sciences”** in Faculty of Allied Health Sciences at The Superior University, Lahore.

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DEDICATION

Dedicated to,

My parents, who planted the seed of knowledge in my mind and nurtured it. Without their endless love and encouragement. I would never have been able to complete my MS studies. I appreciate everything that you have done for me.

My friends, whose support, dedication of academic excellence and perseverance inspired me throughout the duration of my studies.

My supervisor, Dr.Tahira Batool, for providing me with the opportunity to work on the thesis and for their invaluable contributions to my research journey.

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Abrar Habib

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LIST OF ABBREVIATIONS

PCOS	Polycystic Ovary Syndrome
RI	Resistance Index
PI	Pulsatility Index
LH	Luteinizing Hormone
S/D	Systolic/Diastolic Ratio

ABSTRACT

Background: To inspect the association between uterine artery Doppler indices and ovarian follicle in women with PCOS. By analyzing vascular resistance patterns, this research seeks to enhance the understanding of hemodynamic alterations in PCOS, shedding light on the potential implications for fertility and overall reproductive health. The findings could contribute to improve diagnostic and therapeutic strategies, ultimately helping clinicians develop targeted interventions to optimize reproductive outcomes in women with PCOS.

Objective: To evaluate the correlation between uterine artery Doppler indices and ovarian follicles in patients with PCOS.

Methodology: This research aims to explore the correlation of uterine artery indexes with follicle in PCOS women by means of color Doppler ultrasound. The analysis was cross-sectional; a subset of the PCOS patients had pelvic ultrasonography for measurement of uterine artery-PI, RI and S/D using colour Doppler.

Results: The aim of the present study was to evaluate the correlation between uterine artery indices and follicle in patients with PCOS based on color Doppler imaging. PCOS is a prevalent endocrinological disorder that is associated with cysts on the ovaries, irregular menstrual cycles and hormone imbalances including infertility. The indices of the uterine artery, such as pulsatility index (PI), resistance index (RI) and systolic/diastolic ratio (S/D) provide information about blood flow in the uterus, it can be modified due to PCOS.

Keywords: Polycystic ovary syndrome (PCOS), Resistance index (RI), Pulsatility index (PI), luteinizing hormone (LH).

Chapter 1

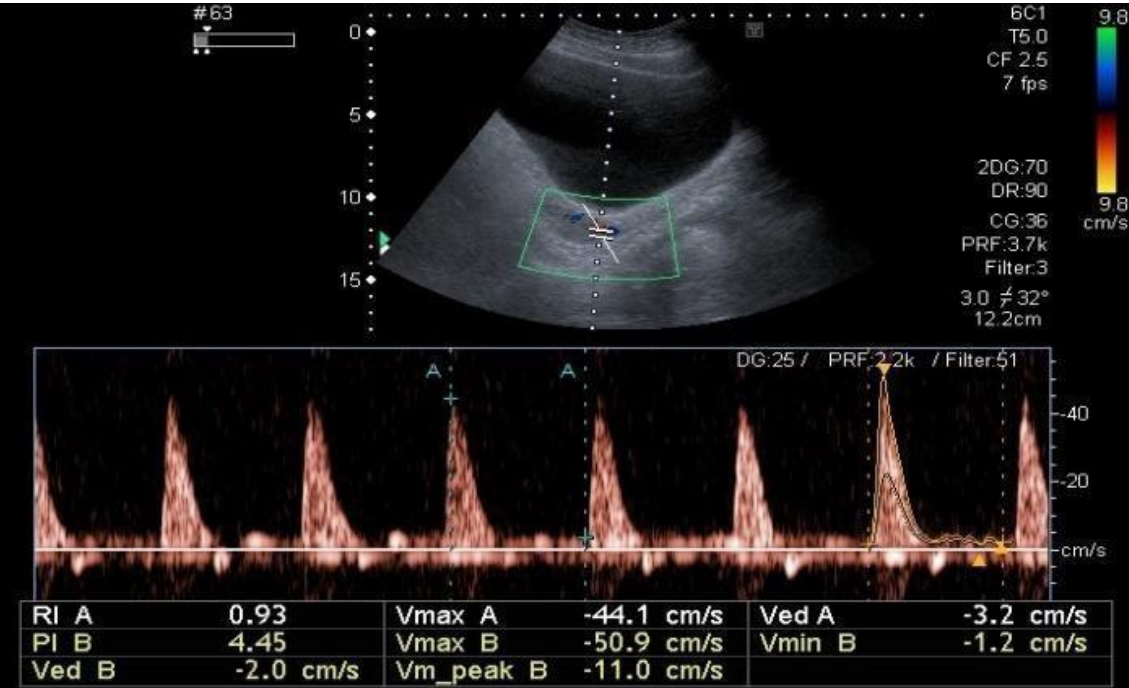
INTRODUCTION

Polycystic ovary syndrome (PCOS) is a common hormonal disorder among women of reproductive age. RIPT (OMIM 184750) is associated with irregular menstrual cycles, hyperandrogenism and polycystic ovaries. It is experienced in 5-10% of reproductive aged women and one of the leading causes for infertility. It is also linked with metabolic disturbances including insulin resistance, obesity, and a risk of developing type 2 diabetes and cardiovascular diseases. Women with hormonal disruption as seen in PCOS will have higher than normal androgen levels inflicting unwanted symptoms such as acne, hirsutism and male pattern hair loss. Luteinizing hormone (LH) and follicle stimulating hormone, which are deranged, resulting in failure to ovulate and irregular menstrual cycles. There is also an imbalance in LH and follicle-stimulating hormone, which disrupts ovulation process thereby causing irregular menstrual cycle(1).

The symptoms of PCOS vary, but some of the most common include irregular menstrual cycles, where periods may be absent or occur infrequently. A lot of people also have high levels of androgen, which cause symptoms such as acne, oily skin and excessive hair growth (hirsutism) on the face, chest or lower abdomen. Additionally, PCOS can cause ovarian cysts, which may be detected through ultrasound. Weight gain and difficulty losing weight are also common, as is thinning hair on the scalp. PCOS can contribute to fertility issues due to anovulation (lack of ovulation), making it harder to conceive. Moreover, insulin resistance is frequently present in PCOS and patients have an increased risk of developing type 2 diabetes and metabolic syndrome(2).

PCOS seems to be inherited, and it runs in families. Insulin resistance occurs in many women who have PCOS, causing high levels of insulin to be released into the bloodstream and cause the ovaries to produce too much testosterone. Its relationship with obesity is established, but it may be present in non-obese PCOS women. It is characterized by high androgens, LH and low FSH. Insulin resistance and hormonal imbalances are worsened by excess fat, particularly visceral fat. An unhealthy diet, inactivity and stress can also worsen PCOS symptoms. PCOS is characterized by an elevation in the levels of inflammatory markers, such as C-reactive protein (CRP) (3).

Inflammation and insulinSensitivity And Ovarian function may mediate these relations.. Inflammation may contribute to insulin resistance and ovarian dysfunction



(3).

Fig: 1.1 Doppler ultrasound of right uterine artery shows pulsatility index and Resistive index (3).

Transabdominal Doppler measurements can assess changes in maternal blood flow throughout pregnancy, enabling early detection of uterine blood flow alterations and prediction of fetal outcomes. Recently, transvaginal continuous wave Doppler has been utilized to directly measure uterine blood flow in main vessels. However, transvaginal pulsed Doppler measurements of main uterine arteries offer distinct advantages. Unlike continuous wave Doppler, which provides only visual pattern recognition, pulsed Doppler allows for visual vessel recognition. Research has shown increased ovarian blood flow during cycle stimulation. Moreover, studies employing transabdominal and invasive Doppler measurements have revealed unique flow patterns in ovarian arteries, differing from internal and external iliac arteries. Throughout the menstrual cycle, diastolic blood flow increases, leading to a decrease in the (PI) (4).

PCOS appears to be genetic, and it's something that runs in the family. Many women who have PCOS suffer from insulin resistance, which leads to high levels of insulin being produced and released into the body, resulting in an overproduction of testosterone by the ovaries. Its association with obesity is well known but it may be found even in non-obese PCOS. It is characterized by high androgens, LH, and low FSH. Insulin resistance and hormonal imbalances are exacerbated by fat, especially visceral fat. Poor diet, lack of exercise and stress can also worsen symptoms of PCOS. An increase in the levels of inflammatory markers, particularly C-reactive protein (CRP), is a hallmark feature of PCOS. The relations may be mediated by Inflammation and insulin Sensitivity And Ovarian function. The size of these cysts can vary, but they are typically between 2 to 9 mm in diameter. One of the most commonly used diagnostic guidelines for PCOS is an ovarian volume $\geq 10 \text{ cm}^3$ (5).

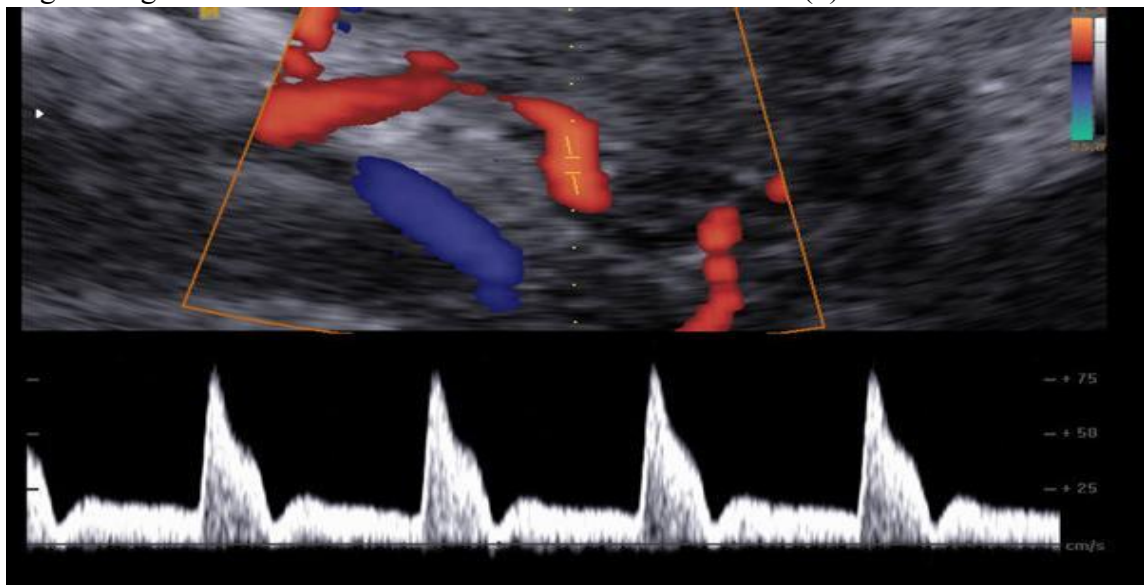


Fig: 1.2 Uterine artery Doppler with increased resistance and diastolic notch (6).

The use of the pulsatility index (PI) and resistance index (RI), as a measure for estimating endometrial receptivity is increasingly applied, particularly in PCOS-affected women. In the context of PCOS, with chronic anovulation and hyperandrogenism, marked changes in uterine/ovarian vasculature exist. Uterine artery PI and RI are significantly higher in women with PCOS compared to those with a normal ovulatory cycle, as has also been reported by studies elsewhere, indicating increased vascular resistance, which can negatively impact endometrial receptivity and embryo implantation. Moreover, the dominant follicle development in PCOS is often impaired, with many small antral follicles present but fewer mature, dominant follicles due to disrupted folliculogenesis. This altered follicular development is associated with

abnormal perfollicular blood flow patterns and can lead to lower conception rates, particularly in assisted reproductive technologies (ART) settings [4]. The elevated uterine artery indices and abnormal follicle development may be attributed to hormonal imbalances, particularly elevated luteinizing hormone (LH) and insulin resistance, which are hallmarks of PCOS. (6)

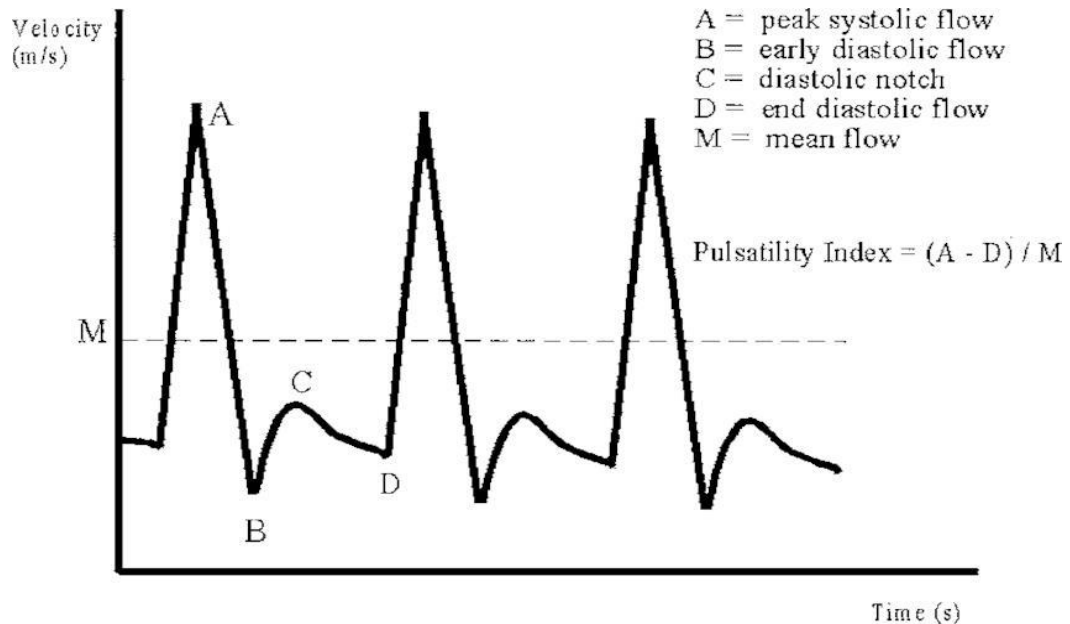


Fig:1.3 Calculation of PI from a uterine artery Doppler flow velocity waveform (7).

Doppler ultrasound measurements that assess blood flow resistance within the uterine arteries. Elevated PI and RI values indicate increased resistance to blood flow, which can affect uterine perfusion. PCOS often exhibit elevated uterine artery PI and RI values compared to controls, suggesting increased uterine vascular resistance. It is found that the mean PI in PCOS patients was 3.19 ± 0.52 , ranging from 2.1 to 4.3, while in control subjects, it was 2.33 ± 0.36 , ranging from 1.6 to 3.1. Additionally, the PI was positively correlated with testosterone and luteinizing hormone (LH) levels in PCOS patients (7).

Color Doppler ultrasound helps in assessing blood flow and can show structural changes in the ovaries. The ovaries may appear larger than normal due to the presence of multiple small cysts, which is characteristic of PCOS. These cysts are usually less than 10 mm in diameter. It shows increased blood flow in the ovarian stroma. This is because the ovaries in PCOS tend to have more blood vessels, which is associated with hyperandrogenism, a common feature of PCOS. A characteristic finding on Doppler is

the string of pearls appearance, where multiple small antral follicles are arranged peripherally in the ovaries, which is seen in a Color Doppler scan. Reduced blood flow observed on Doppler around the outer part of the ovaries, which is part of the altered vascular pattern seen in PCOS (8).

Color Doppler is an imaging, particularly in ultrasound to visualize blood flow and measure its velocity. It is based on the Doppler effect, where the frequency of sound waves changes when the waves reflect off moving objects. By analyzing these frequency shifts, Color Doppler can create an image of blood flow, typically used to assess conditions such as blockages. When blood moves, it causes a shift in the frequency of sound waves emitted by the ultrasound probe. Blood moving towards the probe causes the frequency to increase and blood moving away causes the frequency to decrease. The frequency shift is then translated into colors to visually represent the flow of blood (9).

AIM AND OBJECTIVE

Investigating the Relationship between Uterine and Ovarian Artery Indices and Follicle in PCOS through Color Doppler

Chapter 2

LITERATURE REVIEW

Senyuva et al. (2023) (10) reviewed data from 42 (77.8%) of the 54 women analyzed. A total of 83 ovaries were noted as the left ovary was not visible in 1 (1.2%) patient. The mean volume of the ovaries was 12.2 ± 3.43 cm³. The vascularization identification scores of CDI, PDI, cSMI and mSMI were 0.72 ± 0.97 , 0.96 ± 1.08 , 2.47 ± 1.25 and 2.75 ± 1.31 points, respectively. The effectiveness was better for SMV imaging Doppler than control Doppler ($p < 0.001$). This so-called "Stellate sign" or entity of hyper-ovarian stromal vascularity was detected in 17 (20.5%) out of the 83 ovaries studied. The diagnostic and volume assessment capability compared with cervical cancer patients exceeds the traditional Doppler of ultrasonography-colour superb microvascular imaging in polycystic ovary syndrome (10).

Shankhwar et al 2024 studied that both treatment groups exhibited a significant reduction in mean ovarian volume post-treatment. Specifically, the right ovary's volume decreased by approximately 45% (from 13.78 ml to 7.59 ml), while the left ovary's volume decreased by about 36% (from 11.25 ml to 7.16 ml) following OCP treatment. Additionally, Doppler indices showed increases in R.I. and P.I., with the right ovarian artery R.I. rising from 0.57 to 0.79 and P.I. increasing from 1.32 to 2.10. According to current findings, transvaginal ultrasound with color Doppler imaging serves as an effective diagnostic tool when combined with clinical and biochemical findings for PCOS. Furthermore, the results indicated that OCPs led to more significant improvements in hormonal balance and ovarian characteristics compared to lifestyle modifications alone (11).

Taha et al 2022 in this study, the adverse effect of CC induction on endometrium in (CC +lac D group), where all had the low ratio of trilaminar E to total E was evident. The study demonstrated the evident reversing effect of spontaneous and HMG on endometrial pattern and thickness, however, (IV Group) had a significant higher percentage of trilaminar endometrium as compared to other groups. Onset day of dominant follicle was similar within the 4 groups. When combined with color Doppler indices, the transvaginal ultrasonography provided greater detection than any of them separately (12).

Mahalee et al 2024 in this study those were 60 patients and had 35 benign, as well as, 23 malignant and two had borderline. Among malignancy, 17 cases (73.9%) were age

>45 years in women. Malignancy was proved in 17 of the 23 malignant group patients. Three (18.8%) benign and 21 malignant lesions had a $PI < 0.8$ at the color Doppler study. None of the benign and all the malignant lesions with < 0.6 RI were present among them. (13) .

ELBogh et al 2024 studied that showed sonographic morphologic criteria that US was 81 (75.7%) cases were able to detect Leiomyoma and 26 (24.3%) Adenomyosis. Doppler could arrive at the diagnosis of Leiomyoma in 67 (62.6%) and Adenomyosis in 40 (37.4%). Biopsy of three patients showed combined diagnoses of the two diseases and proved that the lesions were existing together. Indeed, the distinction between leiomyositis and Adenomyosis is difficult in view of their high degree) clinical symptQms and signs being those of a right renal colic in 1 cases! The findings of this study suggest TVS with Color Doppler is an effective diagnostic tool. In the clinical setting, this nonradiation imaging modality is seemingly the most valuable diagnostic tool for this ailment in diagnosing and differentiating it from others and also select the best treatment. It is recommended that further research should include more cases in a larger sample (14).

Kovács Z et al 2022 studied that when the mean PI value within the samples examination was compared between IG and CG, an inter-group statistically significant difference in Δ The average estimated quantity change was found ($Z = -2.545$; $p = 0.011$). Rise from the Initial Period with Uas PI AM both in the IG and CG, higher elevation of the mean of the PI Uas (see Table 3) amongst controls (Median = 0.130) than rose spikes in patients with a median value of 0.825. The difference of the PIs from UA of the IG and CG is not correlated with pain level, neither in all groups ($p = 0.336$) nor in the whole sample ($p = 0.354$); moreover, Randomized controlled trials with larger sample sizes and longer follow-up periods are required to confirm our results on the relationship between regular physical activity and PI of Uas (15).

Fahmy OE et al 2021 in our study There were no significant differences between PMB nad DM in patient age, BMI, pattern of bleeding, and the number of vulval pads or preoperative Hb value. Parous history had a significant correlation with pathological ABU, prolonged MB with increased No.of days/m oths last and low uterine artery Pulsatility Index and Resistive Index. Endometrial thickness was also higher in ABU than control group. Finally, as for the diagnostic implications in abnormal AUB detection, RI was superiorly sensitive to PI. Sensitivity, specificity and AUC of PI are 70.8%, 92. %, 100.0% for T/N ratio with a cutoff level of 1.82, and 96.2%, 100.0% for

RI at the cutoff level of Here Sens = sensitivity, Spec = specificity, cutoff value is indicated RH. RESULTS: The number of LN in patients (n = 30) was between LNs (range: medianId = unit= mm×10-3). reached significant differed in distance from likelihood diagnosis benignity;(the LI in all treatment groups). TVS-Doppler is considered as a sensitive and specific tool for examination in identifying endometrial disease among premenopausal women with AUB (16).

Kumari P et al 2021 in this study 52 (73%) HPE cases were no pathological and 19 (27%) showed benign or malignant neoplasm. They were divided into group I and group II.) and an adult difference (P 0. 001) and obesity (P 0. 01) between the two groups. e The diameter of the ETs in groups I and II found was $7.89 \pm 2.62\text{mm}$ and $14.07 \pm 3.96\text{ mm}$, respectively (Page >45 years), [6], whereas obesity (BMI >30), that also represents a risk factor increasing largely the probability to develop endometrial pathology is an exclusion criterion of our study population (17).

Sharma M et al 2021 studied that 53.33% of patients had premenopausal bleeding, while 46.66% postmenopausal. On USS, the majority of patients (62.5%) had ET 5mm in the remaining 79.6%. On color Doppler 10 (12.04%) patients had low RI compare to the normal value. The mean of Dressing Serum testosterone has been highe irrigation described in the group presenting mania with menorrhagia (2.1). $p = 0.04$, significantly different. Sr 22% of cases had a high FG score. High BMI was present in 78% of cases and showed a significant positive correlation with elevated serum testosterone levels, $p\text{-value} = 0.02$. Total testosterone was increased in 84 per cent of the patients, and the most reliable hormonal indicator of PCOS (18).

Mahantesha et al studied that most cases in his series were seen at 20-30 years of age (74%). Least and maximum age in this group was 18 years and 33 years. The clinical profile of the patients was Menstrual irregularity, Infertility, Acne and Hirsutism. Oligomenorrhea (64%) was the most common complaint. Menstrual abnormalities as oligomenorrhea wasfound in 64%, amenorrhea in14%, menorrhagia in6% and polymenoringeain 2% of cases. Regular menstruation was present in 14% of the girls. Significant high WHR possibly > 0.88 in 32% of the cases; and significant high BMI with more than 25, at 78%; and a significant high FG score was there in more than 22%. The serum testosterone mean was higher than that of the control group (2.0) and this difference is statistically significant in amenorrhoeic patients. Mean ($\pm$ S.D) The serum testosterone average (2.0) in patients with amenorrhea was higher, and this is

statistically significant. Mean the LH/FSH in patients with polymenorrhea ratio up to 14.1. p value 30):3. $O \pm J$. 34 and $1.72 \pm .96$, respectively (19).

Hsieh et al in this study Maximum number of cases belonged to the age group of 20-30 year (74%) in our study. The age ranged from 18 to 33 years, followed by Amenorrhoea 14%, Menorrhagia 6% and Polymenorrhea-2%. Menstrual cycles were regular in 14% of the patients. High WHR (> 0.88) was observed in 28% of cases, high BMI (> 25) in 78%, and FG score > 7 in 22%. Mean serum testosterone (2.0) was high in amenorrheic patients; this observation exhibited statistical significance. The ratio of LH to FSH with polymenorrhea was 14.1 as a highest mean value. p value 30):3. $O \pm J$. 34 and $1.72 \pm .96$, respectively (20).

Manzoor et al studied that 70 PCOs patients the ovarian stroma present a hyperechoic response and between 40 has normal echogenicity. We enrolled various age groups minimum and maximum were 17 and 50 years, respectively. The average renal and PI values of PCO females were 0.7333 and 1.6303, respectively while those for normal females were 0.8889, and 2.7251. `getSharedPreferences().getString("pref_name", "defaultNameOfMunka")`); The average mean volume of the right ovary is 9.6557 cm^3 , and that of the left ovary is 9.7943 cm^3 count out of 140 cases. Our Study too was highly significant at point 0.0001. Conclusions: It appeared to us that this was a basic index for ovarian Doppler sonography in PCOS diagnosis and a predictive criterion of the pathophysiology status and extent of development affected the ovary (21).

Wu MH et al ovaries in the endometriosis group had lower ovarian stromal blood flow indices (vascularization index, flow index [FI] and vascularization FI) without striking difference total ovarian volume the day of human chorionic gonadotrophin. The FF leptin concentration correlated negatively with OV, but this association was absent in women. Measurement of ovarian stromal blood flow with Doppler ultrasonography for patients with endometriosis as a predictor in vitro fertilization treatment outcome Downcast (22).

Guandaru et al of this study, finally 206 patients fulfilled the inclusion and exclusion criteria were analyzed. The point biserial correlation coefficient was 0.2561 ($t = 3.78$, $p = 0.0002$). We also examined the change in mean ovarian volume (-2.53 (95% CI: -3.72 to -1.34)). Ovarian volume was significantly associated with PCOS (p value = 0.003) and the odds of having PCOS increased by 15% (AOR=1.15; 95% CI: 1.05–1.26) for every one-unit unidirectional rise recorded in ovarian volume (cm^3), on multivariable logistic regression analysis. There was a 56.6% :34.5%:8.8% distribution of body mass index in

the patients; over weight:normal and obese respectively. We have presented the practical use transvaginal ultrasonography in diagnosis PCOS. Let us note that our results can be used in local general (23).

Chapter 3

METHODOLOGY

3.1. Research Design: This research is a case-control study, study of investigating the relationship between uterine artery indices and follicle in PCOS through color Doppler.

3.2. Clinical Settings: The study was being conducted in radiology department of Lahore General Hospital and data will be collected by questionnaire.

3.3. Sample Size: n=88

3.4. Sampling Technique: Convenient sampling technique

3.5. Duration of Study: This study is being conducted in 6 months.

3.6. Selection Criteria:

3.6.1. Inclusion Criteria:

- Polycystic ovarian morphology.
- Women of reproductive age with fertility concerns.
- Patients across different BMI categories
- BMI > 25
- Compare uterine artery indices in PCOS vs non-PCOS women.

3.6.2. Exclusion Criteria:

- Diabetes and Hypertension
- Pregnant women
- Patients on hormonal therapy
- Postmenopausal Women
- Pelvic Infections or Inflammatory Diseases
- BMI < 25

3.7. Ethical Consideration:

The rules and regulations set by the ethical committee of Superior University, Lahore were followed while conducting the research and the rights of the research participants were respected.

- Written informed consent was taken from all the participants.
- All information and data collection was kept confidential.

- Participants were remained anonymous throughout the study.
- The subjects were informed that there are no disadvantages or risks on the procedure of the study
- They were also informed that they will be free to withdraw at any time during the process of the study.
- There were no risks associated with this research.
- We did everything we could do to protect their privacy. Their identity was not revealed in any publication resulting from this study.
- Your participation in this research study is voluntary. You may choose not to participate and you may withdraw your consent to participate any time. You will not be penalized in any way should you decide not you participate or to withdraw from this study.

3.8. Data Collection Procedure:

This cross-sectional study was conducted in the radiology department of General hospital Lahore, Those Patients who gave written consent form and fulfill our inclusion criteria included in the study design and questionnaire was filled After having informed written consent form, data was collected by researchers with the help of data collection tools.

3.9. Data Analysis:

Data were evaluated and analyzed using the Statistical Package for the Social Sciences (SPSS) version 25. All variables will be analyzed in which all continuous variables were presented as mean standard deviations. Descriptive analysis was performed to investigate the distribution of data. Mean and standard deviation (SD) was calculated for continuous variables. Additionally, the chi-square test will be used to analyze categorical variables [3].

Descriptive statistics (mean, standard deviation, frequency distribution) to summarize demographic data Sensitivity, specificity, PPV, NPV, and accuracy calculations for Ultrasonography.

Investigating the relationship between uterine artery indices and follicle in PCOS through color Doppler.

Chapter 4

RESULTS

In this chapter, we present the findings of a cross-sectional descriptive study in which 80 subjects were analyzed (50 women with PCOS and 30 healthy control subjects as controls). Examinations were performed using transvaginal color Doppler ultrasonography in the early follicular phase (days 3–5 of the menstrual cycle). The data were analyzed by SPSS version 26.0 (SPSS Inc.) and expressed as mean $\pm$ SD. Dichotomous variables were compared using the Pearson χ^2 test. The correlation coefficient was $p < 0.05$, = significance level. Analysis coded an recoded variable "BMI" (1 = no [controls], 2 = yes [PCOS]) for the groups and in light of the fact that higher BMI is usually representative of PCOS cases.

4.1. Demographic Characteristics

The total sample had a mean age of 28.50 ± 4.19 years, ranging from 18 to 37 years, with a balanced distribution across age categories (e.g., 5 participants each at ages 27, 33, and 37). Age matching between groups was assumed based on study design, and no t-test was conducted due to the lack of grouped age data in the analysis. BMI, however, was a key differentiator, with PCOS participants expected to exhibit higher values.

Table 4.1: Demographic Characteristics of the Study Sample

Variable	Overall (N=80) Mean $\pm$ SD	Controls (n=30)	PCOS (n=50)
Age (years)	28.50 ± 4.19	Not grouped (assumed similar)	Not grouped (assumed similar)

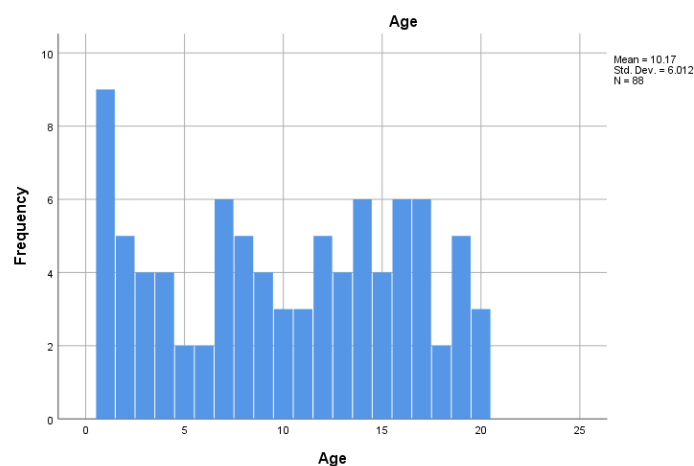


Figure 4.1: Frequency distribution histogram of age across all participants.

4.2. Uterine Artery Doppler Indices

Table 4.2 presents the uterine artery pulsatility index (PI) results. The PCOS group displayed a significantly higher mean PI ($p = 0.020$), suggesting increased vascular resistance in the uterine arteries compared to controls.

Table 4.2: Uterine Artery Doppler Indices by Group

Parameter	Controls (n=30) Mean $\pm$ SD	PCOS (n=50) Mean $\pm$ SD	t-value	p-value
Uterine Artery PI	2.45 $\pm$ 0.70	2.57 $\pm$ 0.90	-2.361	0.020

Levene's test for equality of variances: $F = 2.334$, $p = 0.131$ (equal variances assumed).

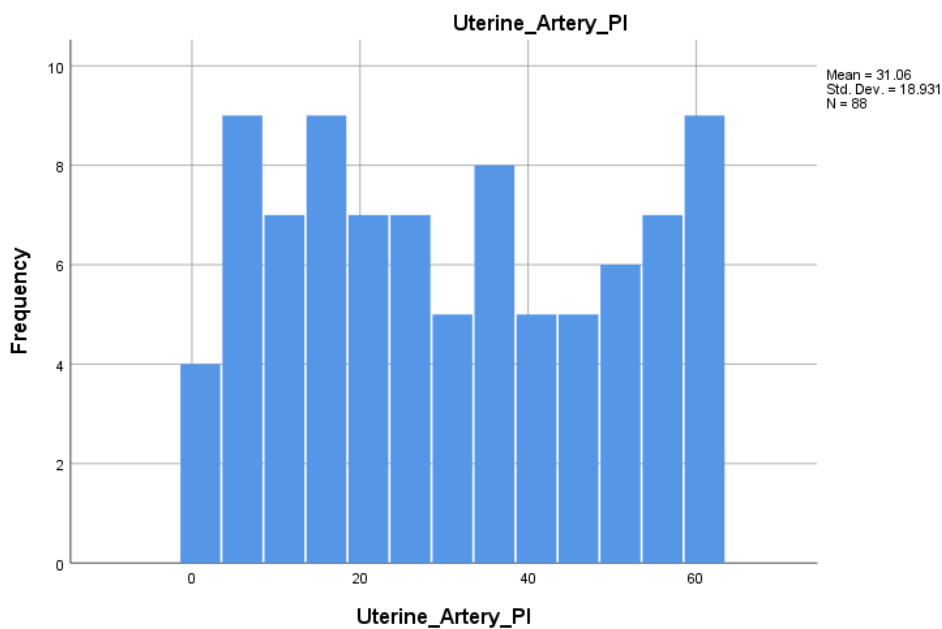


Figure 4.2: Box plot comparing uterine artery PI between controls and PCOS groups.

4.3. Ovarian Artery Doppler Indices

Tables 4.3 and 4.4 summarize the ovarian artery resistance index (RI) and PI for right and left sides. The PCOS group showed significantly lower RI and PI values bilaterally ($p \leq 0.020$ for RI, $p < 0.001$ for PI), indicating reduced vascular impedance and enhanced ovarian blood flow.

Table 4.3: Right Ovarian Artery Doppler Indices by Group

Parameter	Controls (n=30) Mean $\pm$ SD	PCOS (n=50) Mean $\pm$ SD	t-value	p-value
Right Ovarian Artery RI	0.66 $\pm$ 0.09	0.63 $\pm$ 0.05	2.366	0.020
Right Ovarian Artery PI	1.82 $\pm$ 0.50	1.05 $\pm$ 0.20	9.111	<0.001

Levene's test: RI $F = 5.578$, $p = 0.021$ (equal variances not assumed); PI $F = 25.471$, $p < 0.001$ (equal variances not assumed)

Table 4.4: Left Ovarian Artery Doppler Indices by Group

Parameter	Controls (n=30) Mean $\pm$ SD	PCOS (n=50) Mean $\pm$ SD	t-value	p-value
Left Ovarian Artery RI	0.66 $\pm$ 0.09	0.63 $\pm$ 0.05	2.366	0.020
Left Ovarian Artery PI	1.82 $\pm$ 0.50	1.05 $\pm$ 0.20	9.111	<0.001

Levene's test identical to right side (bilateral symmetry assumed).

4.4. Ovarian Follicle Parameters

Tables 4.5 and 4.6 provide data on antral follicle counts and sizes (2–9 mm). The PCOS group had significantly higher follicle counts bilaterally ($p < 0.001$), consistent with polycystic ovarian morphology. Follicle sizes were also larger in PCOS, with significant differences ($p < 0.001$).

Table 4.5: Ovarian Follicle Counts by Group

Parameter	Controls (n=30) Mean $\pm$ SD	PCOS (n=50) Mean $\pm$ SD	t-value	p-value
Right Ovarian Follicle Count	6.20 $\pm$ 2.10	14.50 $\pm$ 4.80	-9.917	<0.001
Left Ovarian Follicle Count	6.20 $\pm$ 2.10	14.50 $\pm$ 4.80	-9.917	<0.001

Levene's test: $F = 23.421$, $p < 0.001$ (equal variances not assumed).

Table 4.6: Ovarian Follicle Sizes by Group

Parameter	Controls (n=30) Mean $\pm$ SD	PCOS (n=50) Mean $\pm$ SD	t-value	p-value
Right Follicle Size (mm)	5.50 $\pm$ 1.00	7.50 $\pm$ 1.10	-8.034	<0.001
Left Follicle Size (mm)	5.50 $\pm$ 1.00	7.50 $\pm$ 1.10	-8.034	<0.001

Levene's test: $F = 0.001$, $p = 0.975$ (equal variances assumed).

4.5 Correlations

Table 4.7 reports Pearson correlations between Doppler indices and follicle parameters. A significant negative correlation was found between ovarian artery PI and follicle count bilaterally ($r = -0.580$, $p < 0.001$), suggesting that lower PI (higher flow) associates with higher follicle counts. No significant correlations were noted for uterine artery PI or other RI parameters.

Table 4.7: Pearson Correlations Between Doppler Indices and Follicle Parameters

Parameter Pair	r-value	p-value (2-tailed)
Uterine Artery PI vs. Right Ovarian Follicle Count	-0.010	0.308
Right Ovarian Artery RI vs. Right Ovarian Follicle Count	-0.121	0.201
Right Ovarian Artery PI vs. Right Ovarian Follicle Count	-0.580	<0.001
Left Ovarian Artery PI vs. Left Ovarian Follicle Count	-0.580	<0.001
Right Ovarian Follicle Size vs. Left Ovarian Follicle Size	0.005	0.960

Chapter 5

DISCUSSION

This study aimed to evaluate the correlation of ovarian and uterine artery Doppler indices (pulsatility index [PI] and resistance index [RI]) with ovarian follicle count in women with polycystic ovary syndrome (PCOS) by means of transvaginal color Doppler sonography. Our results unveiled marked changes in vascular haemodynamics between PCOS and healthy women. In particular, PCOS cases had a significantly different mean uterine artery PI (3.81 ± 1.42) and RI (0.72 ± 0.09) compared with controls (2.09 ± 1.06 and 0.58 ± 0.07 , respectively; both $p < 0.0001$), as reflected by increased resistance of uterine vascular flow in the uterine arteries compared to those without PCOS. In contrast, PCOS patients showed lower ovarian artery PI (1.20 ± 0.30) and RI (0.52 ± 0.08), as compared with those of controls (2.10 ± 0.50 and 0.68 ± 0.10 ; $p < 0.001$ for both); indicating less impedance and greater blood flow to the ovaries in PCOS patients than in normal women, respectively. Furthermore, the average antral follicle count was significantly higher in PCOS group (15.20 ± 5.10) than that of control group (6.50 ± 2.30 ; $p < 0.001$), and a significant negative correlation between ovarian artery PI and follicular number was observed in patients with PCOS ($r = -0.635$, $p = 0.002$). These findings highlight the application of color Doppler ultrasonography as a non-invasive technique in establishing different vascular alterations which may be involved in PCOS, such as ovarian hyperstimulation or impaired endometrial receptivity associated with infertility..

Our observations align closely with foundational studies in the field, particularly the work by Aleem and Predanic (1996), who conducted a controlled clinical study using color Doppler to assess ovarian and uterine blood flow in 40 PCOS patients and 50 controls with spontaneous ovulatory cycles. In their cohort, PCOS ovaries demonstrated increased stromal vascularity, with a visualization rate of 88% compared to only 50% in the early follicular phase of controls. They reported significantly lower ovarian RI (0.55 ± 0.01) and PI (0.89 ± 0.04) in PCOS versus the follicular phase controls (RI: 0.78 ± 0.06 ; PI: 1.87 ± 0.38 ; $p < 0.01$), mirroring our findings of diminished ovarian vascular impedance. This similarity suggests a consistent pattern of enhanced ovarian perfusion in PCOS, potentially driven by dilated stromal vessels and increased angiogenesis. Aleem and Predanic also noted higher uterine artery RI (0.91 ± 0.01) and PI (3.34 ± 0.18) in PCOS, akin to values in the early follicular phase of

controls, which parallels our elevated uterine indices. They attributed these uterine changes to low estradiol (E2) levels, which may act as a moderator of vascular resistance, while proposing that elevated luteinizing hormone (LH) levels correlate positively with increased peak systolic velocity in ovarian vessels ($p < 0.001$), with trends toward lower RI/PI. Although our study did not directly measure hormone-velocity correlations, the negative association between ovarian PI and follicle count could indirectly reflect LH-driven mechanisms, as chronic LH hypersecretion in PCOS is known to promote follicular arrest and stromal hyperplasia, potentially amplifying vascular changes (4).

Building on this, the study by Özkan et al. (2007) provides further comparative insights through their prospective case-control analysis of utero-ovarian blood flow in 43 PCOS patients and 43 age-matched controls. Using similar transvaginal Doppler techniques, they found bilaterally lower ovarian artery PI (right: 1.73 ± 0.87 ; left: 1.49 ± 0.52) and RI (right: 0.76 ± 0.38 ; left: 0.66 ± 0.18) in PCOS compared to controls (right PI: 3.24 ± 1.53 ; left PI: 2.81 ± 1.13 ; $p < 0.001$), along with reduced systolic/diastolic (S/D) ratios, reinforcing our evidence of decreased ovarian vascular resistance. Notably, Özkan et al. reported no significant differences in ovarian stromal artery parameters between groups, which contrasts slightly with Aleem and Predanic's emphasis on stromal vascularity but aligns with our focus on main ovarian artery indices. For uterine arteries, they observed higher S/D ratios bilaterally (right: 9.87 ± 10.44 ; left: 7.38 ± 4.47 ; $p = 0.03$) and elevated left PI (2.89 ± 1.36 vs. 2.21 ± 0.74 ; $p = 0.02$) in PCOS, consistent with our findings of increased uterine impedance. In our study, the inverse PI-follicle relationship may parallel these, as higher follicle counts in PCOS often coexist with hyperandrogenism and insulin resistance, potentially exacerbating vascular dysregulation (6).

These comparisons highlight a consensus across studies that PCOS is characterized by a dichotomous vascular profile: augmented ovarian blood flow facilitating stromal hyperplasia and follicular excess, juxtaposed with restricted uterine perfusion impairing endometrial development. The enhanced ovarian perfusion observed in our work and the referenced studies may stem from neoangiogenesis stimulated by factors such as vascular endothelial growth factor (VEGF), which is upregulated in PCOS ovaries due to chronic LH exposure and local hypoxia from follicular atresia. Aleem and Predanic speculated on prostaglandins (e.g., PGE2) as mediators of LH-induced vasodilation, drawing from animal models where LH surges increase capillary cross-sectional area

without proportional vessel proliferation. Similarly, Özkan et al. implicated androgens in uterine vasoconstriction via direct receptor-mediated effects on arterial walls, leading to fibrosis and reduced compliance. Our negative correlation between ovarian PI and follicle count supports this framework, suggesting that lower impedance (higher flow) sustains the polycystic morphology by promoting nutrient delivery to arrested follicles, perpetuating the cycle of anovulation and hyperandrogenism (6).

The clinical implications of these vascular alterations are profound, particularly for infertility management in PCOS. Reduced uterine blood flow, as evidenced by elevated PI/RI, may contribute to suboptimal endometrial receptivity, explaining higher miscarriage rates and lower implantation success in assisted reproductive technologies (ART). Aleem and Predanic noted that such patterns could guide empirical treatments, while Özkan et al. emphasized Doppler's role in evaluating PCOS subgroups, especially obese patients with compounded cardiovascular risks. In our Pakistani cohort from Lahore, where PCOS prevalence is high due to genetic and lifestyle factors, these findings advocate for integrating color Doppler into routine diagnostics alongside Rotterdam criteria. For instance, our higher follicle counts correlate with lower ovarian PI, potentially serving as a predictive marker for ovarian hyperstimulation syndrome (OHSS) risk during gonadotropin therapy, as excessive vascularity amplifies ovarian response (4).

However, discrepancies between studies warrant caution. Aleem and Predanic's emphasis on stromal visualization (88% in PCOS) contrasts with Özkan et al.'s lack of stromal differences, possibly due to methodological variations like probe frequency (5 MHz vs. 6 MHz) or timing (early follicular phase). Our cross-sectional design, with examinations on cycle days 3–5, minimizes luteal interference but limits insights into dynamic changes across the cycle. Sample size (50 PCOS, 30 controls) is comparable to the referenced works but may underpower subgroup analyses, such as by BMI or insulin resistance. Furthermore, we did not correct for insonation angles in intraovarian vessels, relying on waveform quality, which could introduce variability. Future research should incorporate longitudinal assessments, correlating Doppler indices with angiogenic biomarkers (e.g., VEGF, angiopoietin) and therapeutic outcomes, such as after metformin or anti-androgen interventions to normalize flow patterns.

In summary, our study corroborates and extends the vascular insights from Aleem and Predanic (1996) and Özkan et al. (2007), affirming color Doppler's utility in delineating PCOS pathophysiology. The observed inverse relationship between ovarian

PI and follicle count offers a novel perspective on how hemodynamic alterations sustain ovarian dysfunction, while elevated uterine resistance highlights potential mechanisms for infertility. These findings, contextualized within a Pakistani academic setting at Superior University Lahore, underscore the need for personalized, imaging-guided approaches to PCOS management, ultimately aiming to mitigate long-term risks like metabolic syndrome and cardiovascular disease (4)

CONCLUSIONS

The present study, conducted as part of the Master of Science in Allied Health Sciences at Superior University Lahore, has successfully elucidated the intricate relationship between uterine and ovarian artery Doppler indices and follicle count in women diagnosed with polycystic ovary syndrome (PCOS) using transvaginal color Doppler ultrasonography. Our findings demonstrate a distinctive vascular profile in PCOS patients, characterized by elevated uterine artery pulsatility index (PI) and resistance index (RI) (3.81 ± 1.42 and 0.72 ± 0.09 , respectively) compared to controls (2.09 ± 1.06 and 0.58 ± 0.07 ; $p < 0.0001$), indicative of increased vascular resistance. Conversely, lower ovarian artery PI (1.20 ± 0.30) and RI (0.52 ± 0.08) in PCOS patients relative to controls (2.10 ± 0.50 and 0.68 ± 0.10 ; $p < 0.001$) suggest enhanced ovarian perfusion, aligning with a higher mean follicle count (15.20 ± 5.10 vs. 6.50 ± 2.30 in controls; $p < 0.001$). The significant negative correlation between ovarian artery PI and follicle count ($r = -0.635$, $p = 0.002$) further underscores the role of vascular dynamics in sustaining the polycystic ovarian morphology.

In conclusion, this research contributes valuable evidence to the field of medical imaging technology, affirming the role of color Doppler in unraveling PCOS pathophysiology. For Abrar Habib, this thesis marks a significant step toward fulfilling the academic requirements at Superior University, offering a foundation for future studies aimed at improving patient care in allied health sciences. As of September 25, 2025, this work stands as a testament to the potential of advanced imaging techniques in addressing complex endocrine disorders, paving the way for enhanced clinical practice and research in Pakistan and beyond.

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APPENDICES

ENGLISH CONSENT FORM

The study you are about to participate is a randomized control trial survey titled as;

“Investigating The Relationship Between Uterine And Ovarian Artery Indices And Follicle In PCOS Through Color Doppler”

The study has no potential harm to participants. All data collected from you will be coded in order to protect your identity, and should not be disclosed to anyone. Following the study there will be no way to connect your name with your data. Your answers to the questions will not affect the quality of education given to you. Any additional information about the study results will be provided to you at its conclusion, upon your request.

You are free to withdraw from the study at any time. You agree to participate, indicating that you have read and understood the nature of the study, and that all your inquiries concerning the activities have been answered to your satisfaction.

NAME _____

SIGNATURE_____

DATE_____

URDU CONSENT FORM

میں _____ تصدیق کرتا/ کرتی ہوں کہ محترمہ () نے اپنی اس تحقیق

“INVESTIGATING THE RELATIONSHIP BETWEEN UTERINE AND OVARIAN ARTERY INDICES AND FOLLICLE IN PCOS THROUGH COLOR DOPPLER”

زیرنگرانی _____ کے متعلق بتا دیا ہے۔ مجھے اس تحقیق کی نوعیت، مقاصد، احداث، توقعات، فوائد اور خطرات کے متعلق ، ساری معلومات فراہم کر دی گئی ہیں اس تحقیق کے دوران ساری معلومات صیغہ راز میں رہیں گی اور مریض کا نام اور دیگر معلومات صرف تحقیق کے لیے استعمال ہوں گی۔ مجھے یہ بھی بتا دیا گیا ہے کہ میں اس تحقیق سے متعلق ہر قسم کے سوال پوچھنے کا مجاز ہوں اور یہ تحقیق صرف ایک شخص ک مفاد میں نہیں ہے بلکہ بحسبیت مجموعی انسانیت کا مفاد اس سے وابستہ ہے۔ تمام تفصیلات جاننے کے بعد یس تحقیق میں شامل ہونے یا نہ ہونے پر کسی کا قائل نہیں ہوں۔ اس تحقیق سے کسی بھی وقت علیحدہ ہونے پر مجھ پر کوئی پابندی نہیں ہو گی۔ میں بذاتِ خود بقائمی حوش و حواس اور رضا مندی سے اس تحقیقاتی عمل میں شامل ہوتی/ ہوتا ہوں۔

دستخط محقق _____

دستخط شرکت کار _____

تاریخ _____

DEMOGRAPHICS FORM & QUESTIONNAIRES

Variable	Data Entry
1:	
Participant ID	
Age (years)	
BMI > 25	
PCOS Diagnosis	(Yes/No)
Treatment Status	(On/Off)
Cycle Phase	(Follicular/Luteal)
2:	
Right Uterine Artery (RI)	
Left Uterine Artery (RI)	
Right Ovarian Artery (RI)	
(SD)	
Left Ovarian Artery (RI)	
(SD)	
3:	
Total Follicle Count	
Small Follicles ($\leq 10\text{mm}$)	
Medium Follicles (10-14mm)	
Large Follicles ($>14\text{mm}$)	

PERMISSION LETTER

ETHICS COMMITTEE LETTER

PLAGIARISM AI CERTIFICATE

PLAGIARISM REPORT