THE PLANET

Original Article

Predictive Value of Ovarian Stromal Doppler Ultrasonography for Insulin Resistance in Polycystic Ovary Syndrome

Meer Tahmina Yasmin Mishoe[1*], M A Taher[2], Sharmin Reza Suchi[3]

ARTICLE INFO

Received: 13 July 2026
Accepted: 23 July 2026
Published Online: 27 July 2026

DOI: 10.5281/zenodo.21781781

Volume: 10, Number: 1, Page: 92-96

e-ISSN: 2789-5912
ISSN: 2617-0817

*Corresponding author

ABSTRACT

Background: Polycystic ovary syndrome (PCOS) is a common endocrine disorder frequently associated with insulin resistance, which contributes to both reproductive and metabolic complications. Identification of a reliable, noninvasive marker for insulin resistance may facilitate early risk assessment and management. Aim of the study: To evaluate the predictive value of ovarian stromal Doppler ultrasonography for insulin resistance in women with PCOS and to determine its correlation with Homeostatic Model Assessment of Insulin Resistance (HOMA-IR). **Methods & Materials**: This cross-sectional analytical study was conducted among 65 women aged 18–35 years diagnosed with PCOS according to the Rotterdam criteria. Clinical, anthropometric, biochemical, and hormonal data were collected. Insulin resistance was assessed using HOMA-IR, and participants were categorized into insulin-resistant (HOMA-IR ≥2.5) and non-insulin-resistant (HOMA-IR <2.5) groups. Ovarian stromal Doppler parameters including Resistance Index (RI), Pulsatility Index (PI), Peak Systolic Velocity (PSV), ovarian volume, and stromal area were measured. Correlation, regression n, and receiver operating characteristic (ROC) curve analyses were performed. **Results**: The mean age of participants was 25.8 ± 4.3 years and the mean HOMA-IR was 4.21 ± 2.04. Insulin-resistant women demonstrated significantly lower RI and PI and significantly higher PSV, ovarian volume, and stromal area compared with non-insulin-resistant women (p<0.05). HOMA-IR showed significant negative correlations with RI (r=-0.52) and PI (r=-0.46), while positive correlations were observed with PSV (r=0.59), ovarian volume (r=0.41), and stromal area (r=0.55). Multiple linear regression identified PSV (β=0.38, p<0.001), BMI (β=0.32, p=0.002), RI (β=-0.29, p=0.006), and ovarian volume (β=0.21, p=0.019) as independent predictors of HOMA-IR. ROC analysis demonstrated that PSV had the highest diagnostic accuracy for predicting insulin resistance (AUC=0.84, sensitivity=81.0%, specificity=73.9%). **Conclusion**: Ovarian stromal Doppler ultrasonography is a useful noninvasive tool for predicting insulin resistance in women with PCOS. Among Doppler parameters, PSV exhibited the strongest predictive performance and may serve as a valuable non-invasive surrogate marker for early metabolic risk stratification.

Keywords: *Polycystic ovary syndrome, Insulin resistance, HOMA-IR, Doppler ultrasonography*

1. *Assistant Professor, Department of Radiology & Imaging, BIRDEM, Dhaka, Bangladesh (ORCID: 0009-0004-0985-4923)*
2. *Professor & Senior Consultant, Department of Radiology & Imaging, BIRDEM, Bangladesh*
3. *Assistant Professor, Department of Radiology & Imaging, Cumilla Medical College, Cumilla, Bangladesh*

INTRODUCTION

Polycystic ovary syndrome (PCOS) is a common endocrine and metabolic disorder affecting women of reproductive age and is characterized by ovulatory dysfunction, hyperandrogenism, and polycystic ovarian morphology on ultrasonography [1]. Beyond its reproductive manifestations, PCOS is closely linked to insulin resistance, a fundamental metabolic abnormality that contributes substantially to the development of the syndrome and increases the risk of long-term complications such as type 2 diabetes, metabolic syndrome, and cardiovascular disease [2]. Globally, PCOS affects approximately 8%-13% of reproductive-aged women and 3%-11% of adolescent girls, depending on the diagnostic criteria used and the population studied, making it one of the most prevalent endocrine disorders among women worldwide [3]. In Bangladesh, the prevalence of PCOS has been reported to range from approximately 6.9% to 18%, reflecting variations in diagnostic approaches and population characteristics [4]. Insulin resistance is a key mechanism underlying PCOS and is observed in a substantial proportion of affected women regardless of body mass index [5]. Reduced insulin sensitivity leads to compensatory hyperinsulinemia, which stimulates ovarian androgen production and disrupts normal follicular development [6]. These hormonal alterations contribute to menstrual irregularities, infertility, and metabolic dysfunction. The Homeostatic Model Assessment for Insulin Resistance (HOMA-IR) is widely used as a practical indicator of insulin resistance; however, it requires laboratory testing and may not always be readily available in routine clinical settings [7]. Recent advances in Doppler ultrasonography have provided new opportunities for evaluating ovarian vascular changes in PCOS. Ovarian stromal Doppler assessment measures blood flow parameters such as resistance index, pulsatility index, and peak systolic velocity, which may reflect underlying hormonal and metabolic disturbances [8]. Increased stromal vascularity has been linked to elevated androgen levels and metabolic abnormalities, suggesting a possible relationship between Doppler findings and insulin resistance [9]. The impact of insulin resistance in PCOS extends beyond reproductive health. It increases the risk of type 2 diabetes mellitus, metabolic syndrome, cardiovascular disease, and adverse pregnancy outcomes [10]. Therefore, identifying reliable and noninvasive markers of insulin resistance is clinically important. Doppler ultrasonography offers several advantages, including being noninvasive, relatively inexpensive, widely available, and easily incorporated into routine gynecological examinations [11]. However, Doppler measurements may be influenced by operator expertise, equipment variability, and physiological factors, which remain important limitations [12]. Although previous studies have investigated ovarian stromal blood flow and metabolic disturbances in PCOS, findings have been inconsistent, and evidence regarding the predictive value of Doppler parameters for insulin resistance remains limited. Many studies have involved small sample sizes or heterogeneous populations, reducing the generalizability of their results [12,13]. The increasing burden of PCOS in both developed and developing countries highlights the need for accessible methods to identify metabolic risk factors at an early stage. Consequently, further research is needed to clarify whether ovarian stromal Doppler ultrasonography can serve as a useful surrogate marker for insulin resistance. This study aimed to evaluate the predictive value of ovarian stromal Doppler ultrasonography for insulin resistance in women with PCOS and to correlate Doppler findings with HOMA-IR values.

METHODS & MATERIALS

This cross-sectional analytical study was conducted in the Department of Radiology & Imaging, BIRDEM, Dhaka, Bangladesh over a period of one year between July 2024 and June 2025. A total of 65 women diagnosed with PCOS were enrolled consecutively. The diagnosis of PCOS was established according to the Rotterdam criteria (2003) [14], requiring the presence of at least two of the following three features: (1) oligo/anovulation, (2) clinical or biochemical hyperandrogenism, and (3) polycystic ovarian morphology on ultrasonography, after exclusion of other endocrine disorders.

Inclusion Criteria:

- Women aged 18–35 years.
- Diagnosed with PCOS according to Rotterdam criteria.

Exclusion Criteria:

- History of diabetes mellitus or use of insulin-sensitizing agents.
- Pregnancy or lactation.
- Thyroid dysfunction, hyperprolactinemia, or congenital adrenal hyperplasia.
- History of ovarian surgery or ovarian tumors.
- Use of hormonal therapy within the previous three months.

Ethical Considerations

Ethical approval for this study was obtained from the Institutional Ethical Review Committee before commencement of the research. Written informed consent was obtained from all participants after explaining the study objectives and procedures. Participation was entirely voluntary, and participants were assured of confidentiality, anonymity, and their right to withdraw from the study at any stage without any consequences.

Data Collection

After obtaining informed written consent, demographic and clinical information of all participants were collected using a predesigned and structured questionnaire. Data regarding age, marital status, menstrual history, family history of diabetes mellitus, presence of hirsutism, and acne were recorded. Anthropometric measurements including height and weight were measured following standard procedures, and body mass index (BMI) was calculated as weight in kilograms divided by the square of height in meters (kg/m²).

Following an overnight fast of 8–12 hours, venous blood samples were collected from each participant for biochemical analysis. Fasting blood glucose (FBG), fasting serum insulin, luteinizing hormone (LH), follicle-stimulating hormone (FSH), and total testosterone levels were measured using standard laboratory methods. Insulin resistance was assessed using the Homeostasis Model Assessment of Insulin Resistance (HOMA-IR), calculated according to the formula: HOMA-IR = [Fasting Insulin (μIU/mL) × Fasting Blood Glucose (mg/dL)]/405. Based on HOMA-IR values, participants were categorized into two groups: non-insulin resistant (HOMA-IR <2.5) and insulin resistant (HOMA-IR ≥ 2.5).

Ultrasonographic and Doppler examinations were performed by an experienced radiologist using a high-frequency transvaginal transducer (5–9 MHz). For unmarried participants, transabdominal ultrasonography with a full bladder was performed. Ovarian morphology was assessed, and ovarian volume and stromal area were measured according to standard protocols. Color Doppler ultrasonography was subsequently used to evaluate ovarian stromal blood flow. Doppler parameters including stromal Resistance Index (RI), Pulsatility Index (PI), and Peak Systolic Velocity (PSV) were recorded from both ovaries, and the average of the two measurements was used for statistical analysis.

Statistical Analysis

Data were analyzed using Statistical Package for the Social Sciences (SPSS) version 26.0. Continuous variables were expressed as mean ± standard deviation (SD). Categorical variables were presented as frequency and percentage. Independent sample t-test was used to compare Doppler parameters between insulin-resistant and non-insulin-resistant groups. Pearson's correlation coefficient was used to assess the relationship between HOMA-IR and Doppler parameters. Multiple linear regression analysis was performed to identify independent predictors of HOMA-IR. Receiver Operating Characteristic (ROC) curve analysis was conducted to determine the diagnostic performance and optimal cut-off values of Doppler parameters for predicting insulin resistance. A p-value of less than 0.05 was considered statistically significant.

RESULT

The mean age of the participants was 25.8 ± 4.3 years and the mean BMI was 28.7 ± 5.1 kg/m². Most participants were married (60.0%). A family history of diabetes was reported by 27.69% of the participants. Clinical manifestations commonly associated with PCOS were frequently observed, with hirsutism present in 64.62% and acne in 44.62% of the women. The mean duration of menstrual irregularity was 4.2 ± 2.5 years (*Table I*).

Table I
Baseline characteristics of study participants (*n*=65).

Variables	Frequency (n)	Percentage (%)
Age (years), Mean ± SD	25.8 ± 4.3	
BMI (kg/m²), Mean ± SD	28.7 ± 5.1	
Married	39	60.00
Family history of diabetes	18	27.69
Hirsutism	42	64.62
Acne	29	44.62
Duration of menstrual irregularity (years), Mean ± SD	4.2 ± 2.5	

The biochemical assessment of the study population demonstrated a mean fasting blood glucose level of 96.7 ± 12.5 mg/dL and a mean fasting insulin level of 17.9 ± 8.1 μIU/mL. The average HOMA-IR was 4.21 ± 2.04. Regarding hormonal parameters, the mean total testosterone level was 0.81 ± 0.29 ng/mL. The mean LH and FSH levels were 9.5 ± 3.8 IU/L and 5.7 ± 1.9 IU/L, respectively, resulting in a mean LH/FSH ratio of 1.78 ± 0.74 (*Table II*).

Table II
Biochemical characteristics of the study population.

Variables	Mean ± SD
Fasting Blood Glucose (mg/dL)	96.7 ± 12.5
Fasting Insulin (µIU/mL)	17.9 ± 8.1
HOMA-IR	4.21 ± 2.04
Total Testosterone (ng/mL)	0.81 ± 0.29
LH (IU/L)	9.5 ± 3.8
FSH (IU/L)	5.7 ± 1.9
LH/FSH Ratio	1.78 ± 0.74

The ovarian stromal Doppler ultrasonographic evaluation revealed a mean stromal resistance index (RI) of 0.52 ± 0.08 and a mean pulsatility index (PI) of 0.84 ± 0.19. The mean PSV was 14.6 ± 3.8 cm/s. The mean ovarian volume was 12.9 ± 3.6 mL, whereas the mean stromal area was 3.8 ± 1.1 cm² (*Table III*).

Table III
Ovarian stromal doppler ultrasonographic findings.

Doppler Parameters	Mean ± SD
Stromal Resistance Index (RI)	0.52 ± 0.08
Stromal Pulsatility Index (PI)	0.84 ± 0.19
Peak Systolic Velocity (PSV) (cm/s)	14.6 ± 3.8
Ovarian Volume (mL)	12.9 ± 3.6
Stromal Area (cm²)	3.8 ± 1.1

Participants with insulin resistance had significantly lower stromal RI (0.49 ± 0.08 vs. 0.57 ± 0.07) and PI (0.78 ± 0.17 vs. 0.95 ± 0.18), whereas PSV (15.9 ± 3.7 vs. 12.3 ± 2.8 cm/s), ovarian volume (13.9 ± 3.8 vs. 10.9 ± 2.7 mL), and stromal area (4.2 ± 1.0 vs. 3.1 ± 0.8 cm²) were significantly higher in the insulin-resistant group. HOMA-IR showed significant negative correlations with RI (r = -0.52) and PI (r = -0.46), while positive correlations were observed with PSV (r = 0.59), ovarian volume (r = 0.41), and stromal area (r = 0.55) (all $p < 0.05$) (*Table IV*).

Table IV
Comparison of doppler findings according to insulin resistance and their correlation (*n*=65).

Variables	HOMA-IR <2.5 (n=23)	HOMA-IR ≥2.5 (n=42)	Correlation coefficient (r)	p-value
RI	0.57 ± 0.07	0.49 ± 0.08	-0.52	<0.001
PI	0.95 ± 0.18	0.78 ± 0.17	-0.46	<0.001
PSV (cm/s)	12.3 ± 2.8	15.9 ± 3.7	0.59	<0.001
Ovarian Volume (mL)	10.9 ± 2.7	13.9 ± 3.8	0.41	0.002
Stromal Area (cm²)	3.1 ± 0.8	4.2 ± 1.0	0.55	<0.001

Multiple linear regression analysis identified PSV (β = 0.38, $p < 0.001$), BMI (β = 0.32, p = 0.002), RI (β = -0.29, p = 0.006), and ovarian volume (β = 0.21, p = 0.019) as independent predictors of HOMA-IR. Among these variables, PSV showed the strongest positive association with insulin resistance (β = 0.38, SE = 0.09, $p < 0.001$) and RI exhibited a significant inverse relationship (β = -0.29, SE = 0.11, p = 0.006) (*Table V*).

Table V
Multiple linear regression analysis for predictors of HOMA-IR.

Variables	β coefficient	Standard Error	p-value
PSV	0.38	0.09	<0.001
RI	-0.29	0.11	0.006
Ovarian Volume	0.21	0.08	0.019
BMI	0.32	0.1	0.002

ROC analysis revealed that PSV was the most accurate Doppler marker for predicting insulin resistance, yielding an AUC of 0.84 (95% CI: 0.74–0.93) at a cut-off value of >14.2 cm/s, with 81.0% sensitivity and 73.9% specificity ($p < 0.001$). RI also demonstrated good predictive performance (AUC: 0.79, 95% CI: 0.67–0.90). PI showed moderate accuracy (AUC: 0.75, 95% CI: 0.63–0.87). All Doppler parameters were statistically significant predictors of insulin resistance (*Table VI*).

Table VI
Diagnostic performance of doppler parameters for predicting insulin resistance.

Parameter	Cut-off	Sensitivity (%)	Specificity (%)	AUC (95% CI)	p-value
PSV	>14.2 cm/s	81	73.9	0.84 (0.74–0.93)	<0.001
RI	<0.51	76.2	69.6	0.79 (0.67–0.90)	<0.001
PI	<0.82	71.4	65.2	0.75 (0.63–0.87)	0.002

DISCUSSION

Insulin resistance is a central metabolic disturbance in polycystic ovary syndrome (PCOS), yet its early identification remains challenging in routine clinical practice due to the limitations of conventional diagnostic approaches [15]. The present study evaluated the predictive value of ovarian stromal Doppler ultrasonography for insulin resistance in women with polycystic ovary syndrome (PCOS) and demonstrated significant associations between ovarian stromal blood flow parameters and metabolic dysfunction. The findings revealed that women with insulin resistance had significantly lower stromal resistance index (RI) and pulsatility index (PI), along with higher peak systolic velocity (PSV), ovarian volume, and stromal area. Furthermore, PSV, RI, ovarian volume, and BMI emerged as independent predictors of HOMA-IR, highlighting the potential role of Doppler ultrasonography as a non-invasive tool for identifying insulin resistance in PCOS. The baseline characteristics of the study population were comparable to those reported in previous PCOS studies. The mean age was 25.8±4.3 years and the mean BMI was 28.7±5.1 kg/m², indicating a predominance of young overweight women. Clinical manifestations such as hirsutism (64.6%) and acne (44.6%) were common, reflecting the hyperandrogenic phenotype frequently observed in PCOS. Similar findings were reported by Azziz et al., who observed hirsutism in approximately 80–90% of women with PCOS, emphasizing the close relationship between hyperandrogenism and the syndrome [16]. The metabolic profile of the participants demonstrated a high burden of insulin resistance, with a mean HOMA-IR of 4.21±2.04 and fasting insulin level of 17.9±8.1 µIU/mL. These findings are consistent with the work of Dunaif, who described insulin resistance as a fundamental feature of PCOS affecting at least 50% of affected women [17]. Hyperinsulinemia is known to stimulate ovarian androgen production and contribute to both reproductive and metabolic abnormalities, making early identification of insulin resistance clinically important [18]. A major finding of this study was the significant difference in ovarian stromal Doppler parameters between insulin-resistant and non-insulin-resistant women. Participants had RI and PI values (0.52 ± 0.08 & 0.84 ± 0.19) and PSV value 14.6 ± 3.8 (cm/s). Participants with HOMA-IR ≥2.5 had significantly lower RI and PI values 0.49 ± 0.08 & 0.78 ± 0.17 and significantly higher PSV values 15.9 ± 3.7 (cm/s) compared with those having HOMA-IR <2.5 (RI: 0.57 ± 0.07; PI: 0.95 ± 0.18 & PSV: 12.3 ± 2.8). Moreover, RI and PI showed significant negative correlations with HOMA-IR, whereas PSV demonstrated a strong positive correlation (r=0.59, p<0.001). These results suggest that increasing insulin resistance is associated with reduced vascular resistance and enhanced ovarian stromal perfusion. Similar observations were reported by Battaglia et al., who found significantly lower stromal vascular resistance and increased ovarian blood flow among women with PCOS compared with healthy controls [19]. Likewise, Pourkhani et al. demonstrated increased stromal vascularity and reduced Doppler resistance indices in PCOS, indicating altered ovarian hemodynamics associated with endocrine dysfunction [20]. Multiple linear regression analysis identified PSV, RI, ovarian volume, and BMI as independent predictors of HOMA-IR. Among these variables, PSV showed the strongest predictive value (β coefficient=0.38), suggesting that ovarian stromal blood flow assessment may provide clinically relevant information beyond conventional anthropometric measurements. Similar findings were reported by Battaglia et al., who demonstrated that ovarian stromal Doppler indices remained significant predictors of metabolic abnormalities after adjustment for obesity-related factors [21]. The diagnostic performance analysis further strengthened the clinical relevance of ovarian stromal Doppler ultrasonography. PSV showed the highest predictive accuracy for insulin resistance with an AUC of 0.84, sensitivity of 81%, and specificity of 73.9%, followed by RI and PI. These findings indicate good discriminatory ability and are consistent with previous studies suggesting that Doppler-derived vascular indices can effectively identify metabolically high-risk PCOS phenotypes [11].

LIMITATIONS

- Doppler ultrasonographic measurements are operator-dependent and may be influenced by equipment-related variability.
- Long-term metabolic and reproductive outcomes were not evaluated due to the absence of follow-up.

CONCLUSION & RECOMMENDATIONS

Ovarian stromal Doppler ultrasonography demonstrated significant associations with insulin resistance among women with PCOS. Lower RI and PI values and higher PSV, ovarian volume, and stromal area were observed in insulin-resistant patients. PSV emerged as the strongest independent predictor and showed the highest diagnostic accuracy for identifying insulin resistance. These findings suggest that ovarian stromal Doppler assessment may serve as a practical, noninvasive adjunct for early metabolic risk stratification in women with PCOS. Larger multicenter prospective studies are recommended to validate these findings and establish standardized Doppler cut-off values for routine clinical application.

FUNDING

No funding sources

CONFLICT OF INTEREST

None declared

ETHICAL APPROVAL

The study was approved by the Institutional Ethics Committee.

REFERENCES

1. Eshre R. ASRM-Sponsored PCOS Consensus Workshop Group Revised 2003 consensus on diagnostic criteria and long-term health risks related to polycystic ovary syndrome. Fertil steril. 2004 Jan 1;81(1):19-25.
2. Zhao H, Zhang J, Cheng X, Nie X, He B. Insulin resistance in polycystic ovary syndrome across various tissues: an updated review of pathogenesis, evaluation, and treatment. Journal of ovarian research. 2023 Jan 11;16(1):9.
3. Joham AE, Piltonen T, Lujan ME, Kiconco S, Tay CT. Challenges in diagnosis and understanding of natural history of polycystic ovary syndrome. Clinical endocrinology. 2022 Aug;97(2):165-73.
4. Illiyas SB, Morshed MS, Hasan M, Tofail T, Banu H, Sultana N, Siddika MA, Islam MR, Mahrukh H, Ferdousi T, Roy I. Prevalence of polycystic ovary syndrome by the international evidence-based guidelines: A nationwide cross-sectional survey. Journal of Association of Clinical Endocrinologist and Diabetologist of Bangladesh. 2025 Oct 29;4:S37-.
5. Lim SS, Davies MJ, Norman RJ, Moran LJ. Overweight, obesity and central obesity in women with polycystic ovary syndrome: a systematic review and meta-analysis. Human reproduction update. 2012 Nov 1;18(6):618-37.
6. Diamanti-Kandarakis E, Dunaif A. Insulin resistance and the polycystic ovary syndrome revisited: an update on mechanisms and implications. Endocrine reviews. 2012 Dec 1;33(6):981-1030.
7. Matthews DR, Hosker JP, Rudenski AS, Naylor BA, Treacher DF, Turner R. Homeostasis model assessment: insulin resistance and β-cell function from fasting plasma glucose and insulin concentrations in man. diabetologia. 1985 Jul;28(7):412-9.
8. Aleem FA, Predanic M. Transvaginal color Doppler determination of the ovarian and uterine blood flow characteristics in polycystic ovary disease. Fertility and sterility. 1996 Mar 1;65(3):510-6.
9. Ozdemir O, Sari ME, Kalkan D, Koc EM, Ozdemir S, Atalay CR. Comprasion of ovarian stromal blood flow measured by color Doppler ultrasonography in polycystic ovary syndrome patients and healthy women with ultrasonographic evidence of polycystic. Gynecological Endocrinology. 2015 Apr 3;31(4):322-6.
10. Escobar-Morreale HF. Polycystic ovary syndrome: definition, aetiology, diagnosis and treatment. Nature Reviews Endocrinology. 2018 May;14(5):270-84.

11. Battaglia C, Battaglia B, Morotti E, Paradisi R, Zanetti I, Meriggiola MC, Venturoli S. Two-and Three-Dimensional Sonographic and Color Doppler Techniques for Diagnosis of Polycystic Ovary Syndrome: The Stromal/Ovarian Volume Ratio as a New Diagnostic Criterion. Journal of Ultrasound in Medicine. 2012 Jul;31(7):1015-24.
12. Dewailly D, Lujan ME, Carmina E, Cedars MI, Laven J, Norman RJ, Escobar-Morreale HF. Definition and significance of polycystic ovarian morphology: a task force report from the Androgen Excess and Polycystic Ovary Syndrome Society. Human reproduction update. 2014 May 1;20(3):334-52.
13. Azziz R, Carmina E, Chen Z, Dunaif A, Laven JS, Legro RS, Lizneva D, Natterson-Horowtiz B, Teede HJ, Yildiz BO. Polycystic ovary syndrome. Nature reviews Disease primers. 2016 Aug 11;2(1):1-8.
14. Rotterdam ESHRE/ASRM-Sponsored PCOS Consensus Workshop Group. Revised 2003 consensus on diagnostic criteria and long-term health risks related to polycystic ovary syndrome (PCOS). Human reproduction. 2004 Jan 1;19(1):41-7.
15. Lewandowski KC, Płusajska J, Horzelski W, Bieniek E, Lewiński A. Limitations of insulin resistance assessment in polycystic ovary syndrome. Endocrine Connections. 2018 Mar 1;7(3):403-12.
16. Azziz R, Amiri M, Bril F, Joham AE, Kelestimur F, Ottey S, Suturina L, Tay CT, Teede H, Yildiz BO, Zhao X. Approach to the patient: hirsutism. The Journal of Clinical Endocrinology & Metabolism. 2025 Oct;110(10):e3503-19.
17. Dunaif A. Insulin resistance and the polycystic ovary syndrome: mechanism and implications for pathogenesis. Endocrine reviews. 1997 Dec 1;18(6):774-800.
18. Wallach EE, Barbieri RL, Smith S, Ryan KJ. The role of hyperinsulinemia in the pathogenesis of ovarian hyperandrogenism. Fertility and sterility. 1988 Aug 1;50(2):197-212.
19. Battaglia C, Artini PG, D'Ambrogio G, Genazzani AD, Genazzani AR. The role of color Doppler imaging in the diagnosis of polycystic ovary syndrome. American journal of obstetrics and gynecology. 1995 Jan 1;172(1):108-13.
20. Pourkhani Z, Moini A, Sadatmahalleh SJ, Arabipoor A, Ahmadi F. The value of ultrasonographic features in diagnosis and prediction of reproductive-metabolic dysfunctions in polycystic ovary syndrome: a narrative review. Middle East Fertility Society Journal. 2026 Mar 9;31(1):19.
21. Battaglia C, Artini PG, Genazzani AD, Sgherzi MR, Salvatori M, Giulini S, Volpe A. Color Doppler analysis in lean and obese women with polycystic ovary syndrome. Ultrasound in Obstetrics and Gynecology: The Official Journal of the International Society of Ultrasound in Obstetrics and Gynecology. 1996 May;7(5):342-6.