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Comparison of ischemia modified albumin levels in serum and follicular fluid of infertile patients with PCOS and without PCOS and the outcome of IVF results

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Abstract
Background: Polycystic ovary syndrome (PCOS) is the most common endocrine disorder causing anovulatory infertility. Chronic Oxidative Stress (OS) is implicated in PCOS pathogenesis and may negatively impact Assisted Reproductive Technology (ART) outcomes. Ischemia-modified albumin (IMA) is a sensitive biomarker reflecting systemic and local oxidative/ischemic conditions. Evaluating IMA simultaneously in serum and Follicular Fluid (FF) provides complementary insights into systemic versus local ovarian redox status.
Aim: This comparative prospective cohort study aimed to investigate and compare the levels of IMA in the serum and FF of infertile women with and without PCOS undergoing *in vitro* fertilization (IVF), and to examine the relationship between IMA levels and IVF outcomes.
Methods: A total of 50 infertile women scheduled for IVF were included: 25 diagnosed with PCOS (Rotterdam criteria) and 25 non-PCOS controls. Patients with significant metabolic comorbidities were excluded. Controlled ovarian stimulation was performed using a flexible GnRH antagonist protocol. Serum and FF IMA concentrations were measured using a competitive ELISA kit. Key outcomes assessed included ovarian response (gonadotropin dose, oocyte yield), embryological competence (MII rate, high-quality embryos), and pregnancy rates (biochemical, clinical, ongoing).
Results: Baseline characteristics were homogenous across groups, except for Anti-Müllerian Hormone (AMH), which was markedly higher in the PCOS group (median 4.2 vs 1.0 ng/mL, $p<0.01$). The study found no statistically significant difference in serum IMA levels between PCOS and control groups (P=0.16). In contrast, follicular fluid IMA concentrations were significantly lower in PCOS patients compared to controls (median 21.4 vs 24.6 ng/mL, P=0.031). Regarding ovarian response, the PCOS group had a significantly lower total gonadotropin dose and yielded significantly higher numbers of retrieved oocytes and embryos. However, oocyte maturity (MII rates) and high-quality embryo percentages were statistically equivalent between the groups. Pregnancy outcomes (biochemical, clinical, ongoing rates) were numerically lower in the PCOS group but did not reach statistical significance. Furthermore, IMA levels (in both serum and FF) did not show a statistically significant correlation with overall pregnancy rates. Follicular fluid IMA did exhibit a negative correlation with BMI and AMH within the PCOS cohort.
Conclusion: Serum IMA levels did not differ significantly between PCOS and non-PCOS women, while follicular fluid IMA levels were significantly lower in PCOS patients. This suggests an altered local oxidative homeostasis in the PCOS follicular microenvironment, potentially due to strong compensatory antioxidant mechanisms. Despite this biochemical variation, IMA levels were not found to be a strong standalone biomarker for predicting oocyte maturity, embryo quality, or IVF success in well-selected PCOS patients utilizing antagonist stimulation protocols. These findings reinforce the complexity of oxidative profiles in PCOS and suggest that local redox balance may be preserved sufficiently to maintain reproductive performance under controlled stimulation.

Keywords: PCOS, IVF, fertility, ischemia modified albumin

Introduction

Background of Infertility and Polycystic Ovary Syndrome (PCOS)

Infertility, defined as the inability to achieve a clinical pregnancy after 12 months or more of regular, unprotected sexual intercourse, is a widespread challenge estimated to affect approximately 8-12% of reproductive-aged couples globally [1].

Polycystic Ovary Syndrome (PCOS) is recognized as the most common endocrine disorder among women of reproductive age and is a predominant cause of anovulatory infertility, contributing to about 25% of all female infertility cases [2, 3]. Its prevalence is reported to range from 5% to 20% depending on the diagnostic criteria used [2, 3]. Diagnosis typically follows the revised 2003 Rotterdam criteria, requiring at least two of the following: oligo- or anovulation, clinical/biochemical hyperandrogenism, and polycystic ovarian morphology [4, 5]. The impact of PCOS on reproductive function is significant, characterized by menstrual irregularities, chronic anovulation, and a heterogeneous constellation of metabolic and hormonal abnormalities [4, 6]. PCOS is strongly associated with insulin resistance (affecting 50-70% of patients), which exacerbates hyperandrogenism and disrupts folliculogenesis [7, 8]. These complex hormonal and metabolic derangements can impair oocyte maturation and negatively affect endometrial receptivity, potentially leading to lower fertilization and implantation rates [6, 9].

Oxidative stress in reproduction and the role of follicular fluid

Assisted Reproductive Technologies (ARTs), particularly *in vitro* fertilization (IVF), are critical interventions used to overcome barriers to conception in infertile patients, including those with ovulatory disorders like PCOS [2, 3]. However, the success of IVF is intimately linked to the quality of the gametes and the environment in which they develop [10].

Oxidative stress (OS), defined as an imbalance where the production of reactive oxygen species (ROS) surpasses antioxidant defenses, is increasingly recognized as a critical factor influencing reproductive physiology and ART outcomes [11]. While ROS are necessary for normal reproductive processes like folliculogenesis and oocyte maturation, excessive ROS can induce cellular damage, compromising oocyte and embryo quality [12, 13]. In women with PCOS, OS is often enhanced due to factors such as chronic low-grade inflammation, insulin resistance, and hyperandrogenism [14]. Assessment of OS in the context of IVF requires evaluating both systemic circulation (serum/plasma) and the local ovarian microenvironment [15, 16]. The follicular fluid (FF), derived from plasma and granulosa/theca cell secretions, is the immediate milieu surrounding the developing oocyte [14, 17]. The redox state of the FF is directly linked to follicle health and oocyte developmental competence [18, 19]. Discrepancies between systemic and follicular OS suggest that local markers may better represent the oocyte microenvironmental status [18].

Ischemia Modified Albumin (IMA) as a Dual Biomarker

Ischemia-modified albumin (IMA) is a non-specific but sensitive biomarker reflecting oxidative stress and ischemic conditions [15]. IMA is an altered form of human serum albumin (HSA) resulting from structural modification at the N-terminus due to exposure to ROS, which reduces its ability to bind transition metals, such as cobalt [20]. IMA levels are elevated in various metabolic disorders, including chronic inflammatory states and PCOS [21].In the ART context, IMA has been investigated due to its potential role in reflecting systemic and localized oxidative stress [22]. Several studies have demonstrated elevated serum IMA levels in women with PCOS, linking the syndrome to systemic redox dysregulation [23, 24]. Furthermore, IMA has been measured in follicular fluid, reflecting local oxidative damage in the ovarian microenvironment [25, 26]. High FF-IMA levels have been associated with impaired oocyte quality and reduced pregnancy success [27]. However, the current evidence regarding IMA in PCOS and IVF outcomes is complex and conflicting [26]. While PCOS is acknowledged as a chronic oxidative condition, some studies report significantly elevated IMA in PCOS, supporting the traditional assumption of heightened stress [28, 29], others have found no significant differences in serum IMA levels or even lower FF IMA values compared to non-PCOS controls [28]. These inconsistencies may stem from differences in patient metabolic phenotypes, disease heterogeneity, or the specific ovarian stimulation protocols used [26]. This study is one of the limited investigations evaluating IMA simultaneously in serum and follicular fluid among infertile women with and without PCOS undergoing IVF treatment. The dual assessment of IMA allows for a comparative analysis of systemic versus localized oxidative stress and provides complementary insights into redox dynamics.

The objective of this comparative prospective cohort study is to investigate and compare the levels of ischemia-modified albumin in the serum and follicular fluid of infertile patients with and without PCOS and to examine their relationship with IVF outcomes.

Materials and Methods

Study Design and Setting

This investigation was conducted as a comparative prospective cohort study. The study took place at the Assisted Reproductive Technology (ART) Center, Kamal Al-Samarrai Hospital and Higher Institute of Infertility and IVF. The data collection spanned a period of one year, starting on the 1st of June 2024 and concluding on the 1st of July 2025. The study protocol was formally reviewed and approved by the Medical Research Ethics Committee at Kamal Al-Samarrai Hospital and Higher Institute of Infertility and IVF. All procedures were carried out in strict accordance with the ethical principles outlined in the Declaration of Helsinki. Before enrollment, written informed consent was obtained from all participants.

Study Population and Recruitment

A total of 50 infertile women scheduled for *in vitro* fertilization (IVF) treatment were included in the study. The participants were divided equally into two groups (n=25 per group):

- **Study Group (PCOS):** 25 women diagnosed with Polycystic Ovary Syndrome (PCOS) based on the revised 2003 Rotterdam ESHRE/ASRM criteria.
- **Control Group:** 25 infertile women without PCOS.

Participants were recruited from patients attending the ART Center. All included patients underwent a comprehensive clinical evaluation and laboratory assessment prior to inclusion.

Inclusion and Exclusion Criteria

- **Inclusion criteria:** Women aged 40 years, Undergoing IVF for causes other than male factor infertility, no use of tobacco products, Willingness to participate and provide written informed consent.
- **Exclusion criteria:** Age > 40 years, Presence of Endometriosis or endometrioma, Uterine factor infertility (including congenital anomalies, leiomyomas, or endometrial polyps), Systemic diseases such as diabetes mellitus or hypothyroidism**,** Use of tobacco products.

The cohort was specifically selected to exclude major metabolic derangements and obesity, factors known to amplify oxidative load, ensuring clinical comparability between groups.

Ovarian Stimulation Protocol

Controlled ovarian stimulation (COS) was managed using a flexible gonadotropin-releasing hormone (GnRH) antagonist protocol. This protocol type was chosen, as antagonist protocols may impose less ischemic stress on the ovary compared to agonist cycles reported in another research.

The starting dose of gonadotropins (Gonal-F, Merck, Halle, Germany and/or Merional, IBSA, Switzerland) was determined individually based on the patient's age, body mass index (BMI), and ovarian reserve.

- The Control group received 150-450 IU/day, starting on cycle day 2 or 3.
- The PCOS group received a starting dose of 150-175 IU/day, beginning on cycle day 2 or 3.

Pituitary suppression was initiated with cetrorelix acetate (Cetrotide, 0.25 mg, Merck, Halle, Germany) on stimulation day 6 or 7. Follicular development was closely monitored using transvaginal ultrasonography (TVUSG) every 2-3 days. Ovulation was triggered when the dominant follicle reached 18 mm in diameter.

Oocyte Retrieval and Embryo Transfer

Oocyte retrieval was performed 35-36 hours post-trigger under TVUSG guidance. After denudation, *in vitro* fertilization (IVF) procedures were conducted. Fertilization was assessed 10-18 hours later. Embryos were cultured until the cleavage stage (day 2-3) or the blastocyst stage (day 5), depending on clinical judgment.

Embryo transfer was performed according to national guidelines, involving the selection of good-quality embryos and transferring a maximum of 1-2 embryos.

Luteal Phase Support and Pregnancy Assessment

Luteal support commenced on the day of oocyte retrieval. Patients received vaginal progesterone (Progestan, Koçak Farma, Turkey) at a dose of 200 mg two times daily. Additionally, subcutaneous progesterone (50 mg one time daily) or oral dedrogesterone (two times daily) was administered starting on day 4 after embryo transfer.

Pregnancy outcomes were categorized as follows:

- **Biochemical pregnancy:** Defined as serum beta hCG > {50 U/L} on day 14 after embryo transfer.
- **Clinical pregnancy:** Defined by the detection of a gestational sac with fetal cardiac activity confirmed by TVUSG at 5-6 weeks gestation.
- **Ongoing pregnancy:** Defined as pregnancy continuing beyond 24 weeks of gestation.

Sample Collection and Processing

Samples were collected at the time of oocyte retrieval

- **Blood samples:** 2 mL of venous blood were drawn into EDTA tubes.
- **Follicular fluid (FF) samples:** Collected from follicles that were {\geq18 mm} in diameter before flushing.

All samples were delivered within 30 minutes to the Department of Medical Biochemistry Laboratory at Kamal Al-Samarrai Hospital and Higher Institute of Infertility and IVF.

Processing Steps

- **Plasma preparation:** Blood samples were centrifuged at 1000 g for 15 minutes at 2-8°C.
- **Follicular fluid preparation:** FF samples were centrifuged at 1000 g for 20 minutes at 2-8°C to ensure the removal of cellular components.
- **Storage:** Both plasma and follicular fluid aliquots were immediately stored at {80°C} until the time of analysis.

Determination of Ischemia Modified Albumin (IMA) Levels

IMA concentrations in both serum and follicular fluid were quantified using a competitive enzyme-linked immunosorbent assay (ELISA) kit (CEA825Hu, Wuhan USCN Business Co., Ltd., China). The assay was performed according to the manufacturer's instructions, and results were expressed in ng/mL. IMA is measured in this context because it reflects oxidative stress and ischemic conditions, serving as a dual biomarker.

Statistical Analysis

Sample Size Calculation

The required sample size was determined using G\Power version 3.08. The calculation indicated that a minimum of 25 patients per group was necessary to detect a large effect size (0.8) at a significance level of 0.05.

Data Analysis

Statistical analysis was conducted using IBM SPSS Statistics version 25.0.

- Descriptive statistics were presented as mean, standard error (SE) for continuous variables or as frequencies (n,%) for categorical variables.
- Data normality was assessed using the Shapiro-Wilk test.
- Since continuous variables were not normally distributed, the Mann-Whitney U test was employed for comparisons between the Control and PCOS groups.
- The Pearson chi-square test was applied for analyzing categorical variables.
- Statistical significance was established at $p < 0.05$.
- Pearson's correlation analysis was used to assess associations between IMA and clinical/embryological parameters within the study groups.

Results

A total of 50 infertile women undergoing controlled ovarian stimulation for *in vitro* fertilization (IVF) were successfully enrolled and completed the study protocol, divided equally into the Control group (N=25) and the Polycystic Ovary Syndrome (PCOS) group (N=25). The distribution of participants between the study groups is shown in Figure 1.

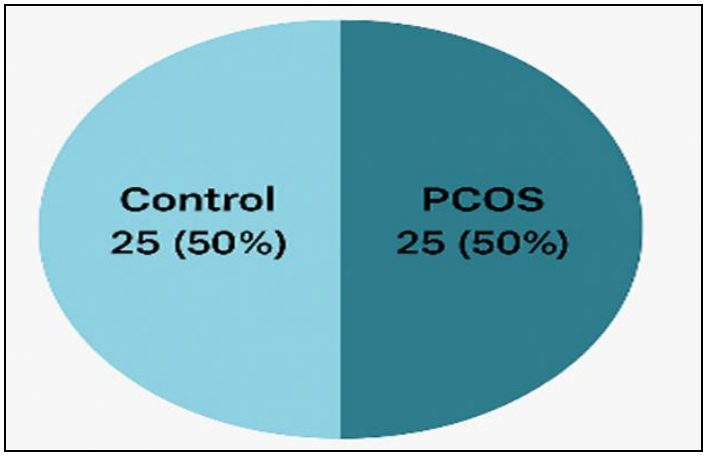

Fig 1: Distribution of study participants according to group classification

Demographic and Clinical Characteristics

Baseline characteristics were determined to be statistically homogeneous across both study groups, ensuring clinical comparability. No significant differences were observed between the Control and PCOS groups concerning median age, body mass index (BMI), or infertility duration ($p > 0.05$ for all variables).In contrast, Anti-Müllerian Hormone (AMH) levels were significantly elevated in the PCOS group (median 4.2 ng/mL; range 1.4-15 ng/mL) compared with the Control group (median 1.0 ng/mL; range 0.09-3.6 ng/mL), confirming the characteristic increase in ovarian follicular reserve associated with PCOS ($p < 0.01$). The detailed baseline demographic and clinical characteristics of the two groups are presented in Table 1.

Table 1: Baseline demographic and clinical characteristics of Control and PCOS groups.

Variable	Control (N=25)	PCOS (N=25)	P-Value
Age (years)	33 (26-39)	32 (23-39)	0.075
BMI (kg/m²)	24.1 (18-37.8)	25.4 (16-40.8)	0.073
Infertility duration (years)	4 (1-13)	4 (1-11)	0.479
AMH (ng/mL)	1.0 (0.09-3.6)	4.2 (1.4-15)	< 0.01
Serum IMA (mg/mL)	24.0 (1.2-40.6)	22.05 (1.43-31.4)	0.16
FF IMA (mg/mL)	24.6 (1.5-46.6)	21.4 (3-41.6)	0.031

Comparison of Ischemia Modified Albumin (IMA) Levels

The study's primary biochemical markers, serum and follicular fluid (FF) Ischemia Modified Albumin (IMA), displayed contrasting patterns between the groups:

- **Serum IMA:** Serum IMA levels showed no statistically significant difference between the PCOS group (median 22.05 ng/mL) and the Control group (median 24.0 ng/mL) (P=0.16). A non-significant trend toward lower systemic IMA values in PCOS was observed.
- **Follicular Fluid (FF) IMA:** FF IMA concentrations were significantly lower in PCOS patients (median 21.4 mg/mL; range 3-41.6 mg/mL) compared with the Control group (median 24.6 mg/mL; range 1.5-46.6 mg/mL) (P=0.031). These differences in serum and follicular fluid IMA between the two groups are illustrated in Figure 3.

This finding suggests that while systemic oxidative stress (serum IMA) did not vary substantially, the local follicular oxidative status, as reflected by FF IMA, was reduced in women with PCOS.

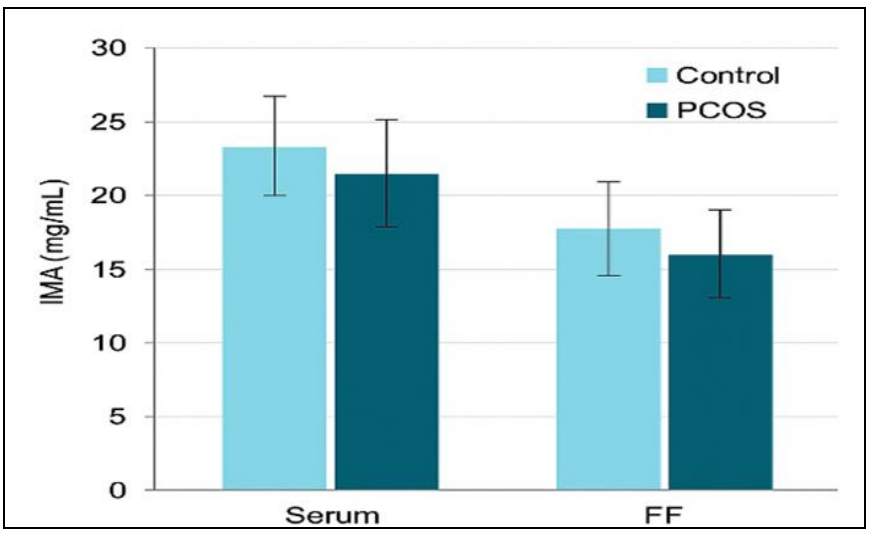

Fig.2 Comparison of serum and follicular fluid IMA levels between Control and PCOS groups

Ovarian Stimulation and Embryological Outcomes

Significant differences were observed in ovarian response parameters:

- **Total Gonadotropin Dose:** The PCOS group required a significantly lower total gonadotropin dose (median 1400 IU) compared with the Control group (median 2250 IU) (p<0.01).
- **Ovarian Yield:** The number of retrieved oocytes (median 15 vs 5) and the number of embryos obtained (median 2 vs 1) were significantly higher in PCOS patients compared to the Control group (p<0.01 and P=0.013, respectively). These ovarian stimulation and embryological data are summarized in Table 2.

Table 2: Ovarian stimulation parameters and embryological outcomes in Control and PCOS groups

Variable	Control (N=25)	PCOS (N=25)	P-Value
Total gonadotropin dose (IU)	2250 (1050-3900)	1400 (325-4750)	< 0.01
Retrieved oocytes (n)	5 (0-18)	15 (2-41)	< 0.01
Embryos obtained (n)	1 (0-11)	2 (0-10)	0.013
MII oocytes (%)	77.7	79.4	NS
High-quality cleavage embryos (%)	92.1	91.1	0.153
High-quality blastocysts (%)	83.3	76.2	0.21

Despite the enhanced ovarian yield, embryo developmental competence remained equivalent between the two groups:

Oocyte Maturity and Embryo Quality: No statistically significant differences were found in the proportion of mature (MII) oocytes (77.7% in Controls vs 79.4% in PCOS), high-quality cleavage embryos (92.1% vs 91.1%, P=0.153), or high-quality blastocysts (83.3% vs 76.2%, P=0.21) between Control and PCOS patients.

Pregnancy Outcomes

Analysis of pregnancy outcomes demonstrated a trend toward lower success rates in the PCOS group, although the differences failed to reach statistical significance.

- **Biochemical Pregnancy:** Occurred in 56.1% of Controls versus 46.6% in PCOS cycles (P=0.08).
- **Clinical Pregnancy:** Achieved in 49.1% of Controls versus 39.3% in PCOS cycles (P=0.293).
- **Ongoing Pregnancy:** Observed in 40.4% of Controls versus 28.6% in PCOS cycles (P=0.188). These pregnancy outcomes are presented in Table 3, demonstrate a downward trend in pregnancy success among PCOS patients, though the variation was not statistically meaningful. This trend is illustrated graphically in Figure 2.

Table 3: Pregnancy outcomes in Control and PCOS groups.

Outcome	Control (N=25)	PCOS (N=25)	P-Value
Biochemical pregnancy (%)	56.1	46.6	0.08
Clinical pregnancy (%)	49.1	39.3	0.293
Ongoing pregnancy (%)	40.4	28.6	0.188

Comparison of serum and FF IMA levels between participants who achieved pregnancy and those who did not revealed no statistically significant differences for either marker.

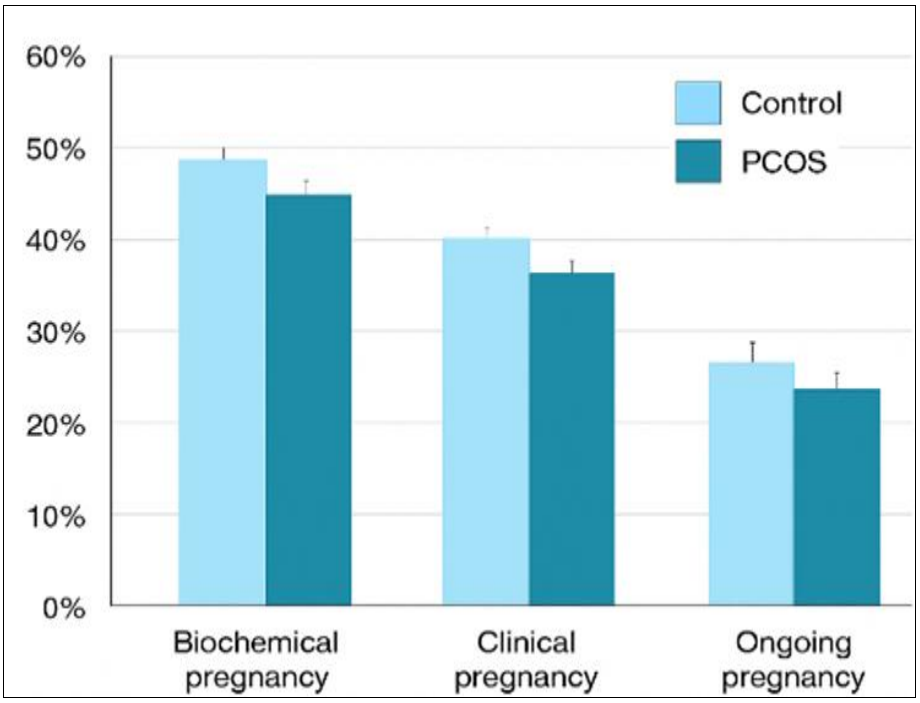

Fig 3: Comparison of pregnancy outcomes between Control and PCOS groups

Correlation Analysis

Pearson's correlation analysis was performed within the PCOS cohort to assess associations between IMA levels and clinical/embryological parameters:

- **Follicular Fluid IMA:** FF IMA exhibited a negative correlation with BMI (r = -0.312, P=0.027) and AMH (r = -0.298, P=0.035) in the PCOS cohort. This suggests that higher ovarian reserve and body mass in PCOS patients were associated with lower levels of local oxidative stress.
- **Serum IMA:** Serum IMA showed no significant correlations with AMH or BMI (p>0.05).
- **IMA vs. Outcomes:** Neither serum IMA nor FF IMA showed significant correlations with total oocytes, MII oocytes, fertilization rate, or overall pregnancy rate in the PCOS group. The full correlation matrix between serum/FF IMA and clinical/embryological parameters is presented in Table 4.

Table 4: Correlation between serum and follicular fluid IMA levels and clinical/embryological parameters in the PCOS group

Parameter	Follicular Fluid IMA (*r*)	P-Value	Serum IMA (*r*)	P-Value
BMI	−0.312	0.027	−0.105	NS
AMH	−0.298	0.035	−0.082	NS
Total oocytes	+0.211	NS	+0.119	NS
MII oocytes	+0.188	NS	+0.092	NS
Fertilization rate	+0.145	NS	+0.073	NS
Pregnancy rate	+0.102	NS	+0.065	NS

Subgroup Analysis by Ovarian Response

The study also compared serum and FF IMA concentrations among different responder subgroups within the PCOS group (Normal, Hyper-, and Poor responders). Although IMA levels appeared slightly reduced in the hyper-responder subgroup, the overall differences in both serum and FF IMA among the three response groups were not statistically significant (p > 0.05). Here the author(s) should be presented the clear and concise findings of the experiment/study. It should be written in past tense. The results should be given here without any references.

Discussion

The present study is one of the limited investigations to simultaneously evaluate ischemia-modified albumin (IMA) in both serum and follicular fluid (FF) among clinically comparable infertile women with and without Polycystic Ovary Syndrome (PCOS) undergoing *in vitro* fertilization (IVF) treatment. The primary aim was to clarify the interplay between systemic and localized oxidative stress (OS) and reproductive performance during controlled ovarian stimulation (COS).

The Ischemia Modified Albumin Levels in PCOS

Consistent with the established pathophysiology of the syndrome, the Anti-Müllerian Hormone (AMH) levels were significantly elevated in the PCOS group, confirming the characteristic increase in ovarian follicular reserve [3, 4]. However, the analysis of the oxidative stress marker, IMA, yielded a paradoxical biochemical pattern in the follicular microenvironment [3].

- **Systemic IMA:** Serum IMA levels did not differ significantly between the PCOS and Control groups. There was even a non-significant trend toward lower systemic IMA values in the PCOS patients [8]. This finding contradicts several earlier studies that reported significantly increased serum IMA concentrations in PCOS, often attributed to chronic oxidative stress and androgen-driven inflammatory processes [9].
- **Follicular IMA:** In contrast, FF-IMA concentrations were significantly lower in PCOS women compared to controls [3]. This result contradicts the traditional assumption that oxidative stress within the follicular niche is heightened in PCOS and negatively impacts oocyte quality [12, 13].

Several factors contribute to this observed inconsistency and the finding of lower FF-IMA in PCOS:-

- **Patient Phenotype:** The discrepancy may be attributed to differences in clinical phenotypes [14]. The PCOS cohort in this study consisted of relatively young women with normal BMI and without major metabolic comorbidities such as obesity, diabetes mellitus, or insulin resistance, factors known to amplify oxidative load and consistently show higher IMA levels in other research [8]. The exclusion of these factors likely reduced the background ischemia-mediated oxidative load [17, 21].
- **Compensatory Antioxidant Mechanisms:** The significantly lower FF-IMA levels may reflect a strong compensatory antioxidant response within the ovarian follicles [30]. This aligns with reports suggesting that systemic oxidative stress does not always mirror local follicular oxidative status in PCOS [30]. It has been suggested that preserved mitochondrial function and increased follicle count in PCOS may help dilute oxidative damage per follicle, thereby lowering IMA formation [18].
- **Stimulation Protocol:** The use of the flexible GnRH antagonist protocol in this cohort may impose less ischemic stress on the ovary compared to agonist-based cycles reported elsewhere [8].

Relationship between IMA, Ovarian Response, and Embryo Quality

The biochemical redox alterations observed did not translate into detectable impairment in gametogenic maturation [31, 32]. Consistent with their elevated AMH, PCOS patients required a significantly lower total gonadotropin dose and yielded a significantly higher number of retrieved oocytes and embryos [31].

Despite the high ovarian yield and the detected difference in FF IMA, the study demonstrated that oocyte maturity (MII rate) and the proportion of high-quality cleavage embryos and blastocysts were equivalent between the PCOS and Control groups [31]. This clinically relevant dissociation suggests that, under the utilized antagonist stimulation protocol, the inherent oxidative stress in this specific, metabolically-controlled PCOS phenotype was mitigated, maintaining normal oocyte maturation [19]. This result agrees with previous reports showing no significant differences in embryo quality or oocyte competence between PCOS and normogonadotropic patients despite altered OS markers [31].

Predictive Value for IVF Outcomes

Although biochemical, clinical, and ongoing pregnancy rates

were numerically lower in the PCOS group compared to controls, these differences failed to reach statistical significance [24].

Crucially, comparison of serum and FF IMA levels between participants who achieved pregnancy and those who did not revealed no statistically significant differences for either marker [5]. Therefore, IMA does not appear to be a strong standalone biomarker for predicting IVF success in PCOS patients using antagonist stimulation protocols [5, 29].

This finding contrasts with studies identifying strong correlations between FF-IMA and embryo grade or reduced pregnancy success [20, 33]. The lack of correlation suggests that reproductive failure in this well-selected PCOS cohort may be more attributable to factors beyond follicular oxidative stress, such as endometrial receptivity alterations or insulin-driven vascular dysfunction [24, 34]. The fact that only fresh embryo transfers were evaluated may have contributed to lower pregnancy success in PCOS, as "freeze-all" strategies have been shown to mitigate endometrial desynchrony and improve outcomes [35].

Furthermore, correlation analysis within the PCOS group showed that FF IMA negatively correlated with BMI and AMH. This correlation is consistent with the hypothesis that higher ovarian reserve (high AMH) may biologically support the antioxidant capacity of granulosa and theca cells, thus associating a greater ovarian burden with lower local oxidative stress marker levels [12].

Conclusion

Based on the measurement of the oxidative stress marker ischemia-modified albumin (IMA) simultaneously in the serum and follicular fluid (FF) of infertile women undergoing *in vitro* fertilization (IVF), the study reached several key conclusions regarding the redox status and reproductive performance of women with Polycystic Ovary Syndrome (PCOS). The study confirms that while serum IMA levels did not differ significantly between PCOS and non-PCOS women, follicular fluid (FF) IMA levels were significantly lower in PCOS patients compared to non-PCOS controls. This finding highlights a paradoxical biochemical pattern in the follicular microenvironment, where systemic oxidative stress was comparable, but local oxidative status appeared reduced in the PCOS cohort. This suggests that follicular markers may better represent the oocyte micro environmental status than systemic markers alone. Despite this biochemical variation (lower FF IMA in PCOS), the study determined that oocyte maturity, embryo quality, and pregnancy outcomes were not significantly affected between the two groups. Specifically, embryo developmental competence, reflected in the proportion of mature (MII) oocytes and high-quality cleavage embryos, remained equivalent between PCOS and controls. The clinical, biochemical, and ongoing pregnancy rates were numerically lower in the PCOS group, but these differences did not reach statistical significance. These results indicate that the IMA levels did not translate into detectable impairment in gametogenic maturation under the antagonist stimulation protocol utilized.

Conflicts of interest

Not available

Financial Support

Not available

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