

## Original paper

# Anti-müllerian Hormone Associated with Antral Follicular Count in Cases of Polycystic Ovary Syndrome

Raghad Numan Talib<sup>1</sup>, Maysaloon Adnan Abdul Razzak<sup>2</sup>

<sup>1</sup>Karbala health directorate/ Karbala/ Iraq

<sup>2</sup>College of Medicine/ University of Kerbala/ Karbala/ Iraq

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Correspondence: Maysaloon Adnan Abdul Razzak

Email: maysaloon07707@gmail.com

### Abstract

**Background:** Anti-Müllerian hormone (AMH) synthesized in the “granulosa cells” of the ovarian graffian follicles and can suppress the growth of primordial follicles.

**Objective:** To assess the AMH association with antral follicular count on the 2<sup>nd</sup> menstrual day to evaluate its diagnostic potency in the definition of polycystic ovary syndrome (PCOS).

**Patients and methods:** |A case control study, involving two groups of total hundred infertile women. The first group included fifty PCOS cases, while the controls included 50 non-PCOS infertile cases. Detailed history was obtained from candidates, and on the 2-3 cycle day underwent the following hematological tests: testosterone, follicular stimulating hormone, AMH, luteinizing hormone, and estradiol. As well, transvaginal ultrasonography was performed to assess hormonal/follicular association evaluated by the count of early antral follicles.

**Results:** The AMH levels in the PCOS were significantly higher compared to the controls (13.8±5.9 vs. 6.0±2.6ng/ml), correspondingly. A significant increase in the follicles' count among PCOS women compared to control (17.6±6.8 vs. 8.0±3.8), respectively. AMH correlated significantly high with follicular count in the PCOS group. The levels of AMH and testosterone were significantly correlated in the PCOS group.

**Conclusion:** During the initial follicular phase, AMH in PCOS is strongly correlated with antral follicle status. Such a link is stronger when compared with other hormones affecting follicular function. This could highlight the importance of AMH concentration as superior predictor of the early follicular counts than traditional hormonal assays. Hence, AMH levels offer a good diagnostic potency in the definition of PCOS.

**Keywords:** PCOS, antral follicle count, (AFC), AMH, and infertility.

### Introduction

Infertility is distressing nearly 15%- 20% of couples attempting gestation as a common medical problem <sup>(1)</sup>. Polycystic ovarian syndrome (PCOS) represents a major reason for female infertility and a common gynecological illness distressing around 15% of females during reproductive years <sup>(2)</sup>. PCOS is a multifaceted, heterogeneous syndrome of undefined etiology, nevertheless, environmental, life-style factors, and hereditary, remain controversial <sup>(3)</sup>. PCOS is characterized by the incidence of the following as defined by “Rotterdam criteria, National institute of health (NIH), and Androgen Excess PCOS Society”: oligo/anovulation, androgen excess and micropolycystic syndrome (ovarian size more than 10ml and/or >12ovarian follicles), exclusion of other causes of polycystic ovaries <sup>(4)</sup>, <sup>(5)</sup>. Women with PCOS usually will consult for

various extents of androgen excess (acne, hirsutism, seborrhea), menstrual disorders, overweight, and infertility <sup>(2)</sup>.

Anti-müllerian hormone (AMH) is a valuable laboratory investigation for infertility assessment. AMH is synthesized by granulosa cells (of early ovarian follicles) and used to assess the reserve of the ovaries. AMH is one of the “transforming growth factor-β (TGF-β) family” that also includes activin and inhibin <sup>(6)</sup>. AMH serum concentrations remain steady through menstruation since its synthesis is independent of gonadotropin levels <sup>(7)</sup>. Patients with PCOS reveal AMH values 2-3 times more than non-PCOS females owing to increased antral follicles. The raised AMH levels revealed an association with the severity of PCOS in other studies <sup>(8)</sup>. Transvaginal ultrasonography (TVUS) is a useful tool to assess the endometrial thickness,

antral follicle count (AFC), and analyze uterine anomalies<sup>(9)</sup>.

Reduced AFC in infertile women shows that factors influencing the quantity of surviving follicles in younger women also affect the quality of oocytes and the likelihood of conception<sup>(10)</sup>. A number of non-invasive indicators, such as FSH, E2, inhibin B, and AMH and AFC, have been developed to evaluate "ovarian reserve"<sup>(11)</sup>. However, some researchers contend that the quantity rather than the quality of the surviving oocytes is what the ovarian reserve predominantly indicates<sup>(12)</sup>. According to a number of studies, ovarian reserve testing does not accurately predict whether women who use assisted reproductive technologies will become pregnant or experience a miscarriage<sup>(13)</sup>. Others, however, contend that high FSH, a sign of inadequate ovarian reserve, is connected to a delay in spontaneous conception regardless of age, an increase in miscarriages, and an earlier age of menopause<sup>(14)</sup>. AMH is a promising diagnostic tool for PCOS as an addition to the current Rotterdam criteria, despite its low sensitivity and specificity and the fact that no single AMH cut-off is diagnostic for the condition<sup>(15)</sup>.

Given this ongoing debate and the scant information currently available, the objective of this study is to assess the relationship between serum AMH levels and AFCs in cases of PCOS.

## Patients and Methods

### Sampling and setting

A case-control within cross-sectional approach study. It was conducted on the patients attending Babylon Maternity and Pediatric Teaching Hospital, throughout the period from (September 2020 to December 2021). The patient group included 50 infertile women (primary and secondary) with PCOs cases diagnosed by the gynecologists at the hospital based on the Rotterdam criteria<sup>(5)</sup> irrespective to other clinical or medical backgrounds of the females. In females with menstrual abnormalities, the previous cycle whether spontaneous or induced by progesterone (10mg/day for one week) was considered. Those with any of the following were omitted from this study: unexplained infertility, endometriosis, hypothalamic amenorrhea, and any women with a minimum of one follicle more than 9mm diameter at sonography or plasma estradiol (E<sub>2</sub>) concentration exceeding 80pg/ml. The control group comprised 50

infertile women with normal menstruation and without any prior hormonal therapy.

### History and clinical examination

All candidates underwent detailed obstetric and gynecological history. They were comforted regarding the privacy and secrecy of their data and written consent was taken from them. Women were assessed during days 2-3 of the follicular phase. A thorough clinical and physical examination was done. Body mass index (BMI) was measured by calculating the body weight and the patient height.

### Biochemical assays

Hematogenous early-morning sampling was drained during the days 2-3 of the last menstrual cycle (early follicular phase) for the measurement of AMH, Testosterone, Estradiol, LH, and FSH according to the provider's directions. In the PCOS group, the latest period was either natural or induced by the progesterone administration (10mg/day for one week). Any Women with estradiol levels exceeding 80pg/ml were not enrolled. Blood AMH levels were measured through the enzyme immunoassay AMH provided by "Immunotech®, Beckman Coulter company, France". LH, FSH, and E2 were evaluated using the VIDAS technique using enzyme-linked fluorescent assay by Biomerieux®, France.

### Ultrasonographic study and antral follicular count (AFC)

Transvaginal ultrasonography (TVUS) was done on the day of blood sampling, using a "5-MHz vaginal probe, (Philips HD11XE®, Japan)". Real-time measures were made using the best possible ovarian view. A transvaginal scan of the early follicular phase measures the total number of follicles measuring 2-10 mm in diameter. According to the size of the residual follicular pool and the number of oocytes extracted after stimulation, the number of antral follicles (AFC) is correlated with both of these factors. The follicular counts were counted by scanning the two ovaries individually from the inner to the outer borders longitudinally. All ovarian follicles measuring 2.0-9.0mm were totaled. If the dominant follicle was >9mm, the TVUS exam was repeated in the next cycle.

### Statistical method

Statistical evaluations were done using the SPSS Statistics V-20. The descriptive examination was applied to display the means and SD for BMI, ages, and biochemical assays. Contrasts of any two independent sets were prepared through the Student T-test.

The association between AMH and other study variables were evaluated by the Pearson correlation (correlation coefficient). A  $P \leq 0.01$  reflected highly significant and  $p \leq 0.05$  significant values.

## Results

### Demographic characteristics

The study comprised a total of 100 women aged 20-44 year; the mean age and SD ( $31.3 \pm 4.3$  year). They were divided into two groups as shown in table-1. The control set comprised 50 patients (21.4-43.0 years old) and a mean of  $34.2 \pm 5.4$  year presented with infertility due to non-PCOS causes. 28 (56%) women were complaining of primary infertility and 22 (44%) women with secondary infertility of 2-9.4 year duration. Their BMI ranged between 22.7 and  $32.4 \text{ Kg/m}^2$ , and in 76% of them the BMI was  $> 25 \text{ kg/m}^2$ .

The fifty PCOS women had ages ranging from 20.5 to 41.8 year, and a mean of  $32.4 \pm 6.2$  year. Their BMI ranged from 20 to  $38.4 \text{ kg/m}^2$  and in 84% of them the BMI was  $> 25 \text{ kg/m}^2$ . Primary infertility was the main complaint of 60% of them for a mean duration of  $5.4 \pm 2.8$  year. There were no statistically significant variations in the mean of the two study groups for the age, BMI, parity, and duration of parity. Sixteen of the PCOS women had amenorrhea

(30%), 26 of them had oligomenorrhea (62%) and eight (8%) of them had a regular cycle (table-1).

Table (2) shows the menstrual status of the PCOS group as long as the entire control group had a regular cycle.

Table-3 displays significant differences in testosterone levels between the group of PCOS and the control group ( $P=0.02$ ) with highly significant differences in AMH level and AFC between the two study groups, (0.001 and 0.001, respectively). Distribution of Anti-Mullerian hormone with age and BMI between the study groups

There was a highly significant differences ( $P=0.001$ ) in the levels of AMH among PCOS women aged 25-29 year. As well, there were highly significant differences in the levels of AMH among PCOS women within the BMI subgroups ( $25-35 \text{ Kg/m}^2$ ), (table-4). Pearson correlation revealed that the increase in LH level ( $P=0.07$ ) and the decrease in FSH and estradiol levels were not significant ( $P=0.08$  and  $P=0.11$ ), correspondingly. However, a significant correlation between AMH and testosterone hormone ( $P=0.05$ ) in the cases of PCOS was observed (table 5). There was a significant correlation between the levels of testosterone hormone and the AFCs in the control group and the PCOS group where both of them already increased in the PCOS group, table 6.

**Table 1.** The Demographic features of the PCOS and control groups

Characters		PCOS women N=50		Control women N=50		P-value
		Number	Percentage	Number	Percentage	
Age groups (year)	20-24	10	20	10	20	0.111
	25-29	15	30	8	16	
	30-34	12	24	12	24	
	$\geq 35$	13	26	20	40	
BMI groups $\text{Kg/m}^2$	20-24	8	16	12	24	0.130
	25-29	19	38	17	34	
	30-34	12	24	21	42	
	$\geq 35$	11	22	0	0	
Parity	P <sub>0</sub>	32	64	28	56	0.116
	P <sub>1</sub>	13	26	13	26	
	P <sub>2</sub>	5	10	9	18	
Type of infertility	Primary	30	60	28	56	0.223
	Secondary	20	40	22	44	
Duration of infertility (year)	1-5	23	46	25	50	0.343
	6-10	20	40	15	30	
	$\geq 11$	7	14	10	20	

*The hormonal and ultrasound criteria in PCOS and control groups*

**Table 2.** The menstrual status in the PCOS group

PCOS Group (N=50)		
Menstrual status	N	Percentage
Amenorrhea	16	30
Oligomenorrhea	26	62
Regular cycle	8	8

**Table 3.** The differences in hormonal level (mean±SD) and AFC between study groups

Variables	Patient N=50	Control N=50	P-Value
FSH (mIU/l)	6.9±1.1	7.5±1.9	0.1
LH (mIU/l)	9.4±3.2	8.5±2.4	0.1
E2 (pg/ml)	12.3±9.6	14.9±9.6	0.2
Testosterone (ng/ml)	0.9±0.7	0.7±0.2	0.02
AMH (ng/ml)	13.8±5.9	6.1±2.6	0.001
Antral follicles Counts	17.7±6.7	8.1±3.8	< 0.001

**Table 4.** The distribution of AMH, age groups, and BMI between the study groups, (values are shown as mean ± SD)

Characteristics	AMH (ng/ml)		P-value
	Patient N=50	Control N=50	
Age Group (year)	3.78 5.70) Total (±)	(6.02 ± 2.59) Total	< 0.001
20-24	9.60 ± 3.81	6.13 ± 2.70	0.210
25-29	16.25 ± 4.80	5.96 ± 2.96	0.001
30-34	14.66 ± 6.66	5.2 ± 2.15	0.001
≥35	13.17 ± 5.80	6.35 ± 2.71	0.001
BMI Groups (kg/m <sup>2</sup> )	Total (29.93±5.90)	Total (28.54±2.43)	
20-24	9.15 ± 3.92	4.57± 2.14	0.081
25-29	15.13 ± 6.59	4.74 ± 1.62	0.001
30-34	± 4.87 TZ14.95	8.56 ± 2.23	0.001
≥35	15.65 ± 5.17	N=0	-

The correlation between AMH and other hormones among study groups

**Table 5.** The correlation between levels of AMH and other hormones among the study groups

Hormones	Pearson correlation	Patient N=50	Control N=50
FSH (mIU/l)	r	-0.45	-0.18
	p	0.080	0.211
LH (mIU/l)	r	0.74	-0.166
	p	0.061	0.250
Estradiol (pg/ml)	r	-0.39	0.1
	p	0.091	0.970
Testosterones (ng/ml)	r	0.25	0.63
	p	0.050	0.060

The correlation between the AFC and hormonal level

**Table 6.** Correlation between the hormonal levels and AFCs in PCOS and control group

Hormones	Pearson correlation	Patient N=50	Control N=50
FSH (mIU/l)	r	0.22	0.03
	p	0.112	0.801
LH (mIU/l)	r	0.24	0.04
	p	0.112	0.813
E2 (pg/ml)	r	0.32	0.04
	p	0.083	0.857
Testosterone (ng/ml)	r	0.39	0.04
	p	<b>0.006</b>	0.824

Correlation between AFCs & AMH among study groups

Antral follicular counts were significantly correlated with AMH in healthy infertile women (P-0.01). However, the correlation was highly significant (P-0.001) in cases of PCOS, (table-7). Correlation tables and data within are non-clear and inappropriate and

Table 5, 6, 7, better to be removed as currently tables are not correct or revised (yes, we apologies for this inappropriateness, it was revised accordingly)

**Table 7.** The correlation between the levels of AMH and the antral follicles count

	Pearson correlation	Patient	Control
AFCs	r	0.85	0.36
	p	<b>0.001</b>	<b>00.01</b>

## Discussion

This case-control study intended to assess the relationship between serum concentrations of AMH with the AFCs on days 2-3 of the cycle among infertile women with PCOS. The main findings were significantly higher values of AMH levels and AFC, and significantly higher testosterone levels among the PCOS patients compared with the control women. As well, a significant correlation between the levels of AMH and testosterone hormone among PCOS women was reported. Moreover, the correlation between AFC and plasma AMH in the group of PCOS was highly significant and significant in healthy women.

PCOS women have a higher BMI than that of the control which might owe to the pathophysiology of PCOS due to increasing insulin-resistance and hyperandrogenemia <sup>(16)</sup>. The study revealed a highly significant association between AMH with women aged 25 years and more with PCOS.

There were non-significant variations between the two groups regarding the type of infertility (primary or secondary) because the choice of the participants was according to the cause not on the type of infertility. This was the explanation for no variations in the parity of the two groups.

Several scholars have suggested that AMH is a probable pointer for the follicular pool. AFCs were closely linked with the AMH plasma levels on day 3 of the menstrual cycle in infertile patients, in comparison with other hormones like estradiol, and FSH<sup>(17)</sup>. Later, several revisions found a significant increase in AMH values in PCOS women was related to the AFCs<sup>(18, 19)</sup>.

Results of the control patients in the current study approve the previous reports that displayed a correlation between AMH and the small AFCs found in normal women<sup>(20)</sup>. Van Rooij and his colleagues reported that levels of serum AMH were a good predictor of the count of recovered oocytes<sup>(21)</sup>.

Hence, all the aforementioned data led to the assumption that AMH is a biological indicator of the early follicular phase AFC in fertile and PCOS infertile women. Besides, it was revealed that AMH level was greatly reproducible between cycles, a point that emphasizes its strength as a biomarker of the AFC (22).

A closer look at the current study revealed that AMH was associated significantly with early AFCs than did the other hormones (FSH, LH, and E<sub>2</sub>) that modulate their stimulation by FSH<sup>(23, 24)</sup>. This denotes that serum E<sub>2</sub> values not just depend on the masses of the existing active follicular granulosa cells, (as expressed by follicular count and size, but on their hormonal stimulation by FSH as well.

Consequently, serum AMH levels may signify a more reliable and independent biomarker of early antral follicle physiology than FSH and E<sub>2</sub> on cycle days 2-3. The higher basal AMH values in the PCOS women as compared with normal control of this study confirmed the results of previous researchers who attributed these results to the great AFCs of that observed in PCOS characteristically<sup>(25)</sup>. Nevertheless, it is worth recalling that neither a raised AMH level nor a raised AFCs is by itself adequate to identify PCOS. Hence, both of these criteria should be integrated into the Rotterdam description.

The current study put forward the claim that the AMH levels were closely associated with hyperandrogenemia (high testosterone levels). This is consistent with a recent study that also concluded a positive link between the blood androgens level with AMH in PCOS<sup>(26)</sup>. Testosterone can stimulate the growth of ovarian follicles by enhancing the biological actions of FSH and insulin-like growth factor-1<sup>(27, 28)</sup>. The excessive ovarian production of AMH by ovarian granulosa cells may explain the hyperandrogenism of PCOS.

Overall, the link between AMH with sex body hormones is complex and varying, hence, additional studies are required to specify the correlation. Concordant to our outcomes, Lv PP and his colleagues as well, revealed a positive close association between serum AMH and testosterone levels in PCOS women but not in controls<sup>(28)</sup>. This could signify a positive impact of AMH on “theca interna cells” causing testosterone over secretion and a subsequently increased sum of early growing ovarian follicles, and hence ovarian hyperandrogenism and the biological process of terminal follicular maturation are the most affected.

Alternatively, the available piece of data shows that AMH suppresses the androgen conversion to E<sub>2</sub> via down-regulating the gene expression of the aromatase enzyme<sup>(28)</sup>. This supports the current study finding of a negative link between plasma levels of AMH and E<sub>2</sub> among PCOS women.

Along similar lines, higher AMH values presented by Cook et al. and in the present study were linked with lower levels of FSH and E<sub>2</sub><sup>(25)</sup>. It is therefore attractive to postulate that a high serum AMH is enrolled in the deficiency of FSH-induced aromatase action that describes follicular arresting of the PCOS.

Of note, and since AMH is an initial product (compared to E<sub>2</sub>) from the ovarian follicles, these differences could reflect alterations in the sampling day. In some studies, blood was sampled randomly from oligomenorrheic patients, while our women were tested on days 2-3 after either spontaneous or progestin-induced cycles. Therefore, the means of E<sub>2</sub> levels were higher in the other revisions<sup>(29)</sup>.

Ovarian follicles obtained from experimental AMH-knockout-mice have been displayed to be more FSH-sensitive than those obtained from the wild-

type mice; signifying that the AMH suppressing effect on body aromatase enzyme acts via a decline in sensitivity of granulosa cells to FSH. According to the findings, the infantile increase in FSH levels decreases AMH expression in preantral/early antral follicles, favoring Cyp19a1 aromatase expression and E2 synthesis. This, together with recent findings that AMH can act on both the hypothalamus and the pituitary to boost gonadotropin levels, implies that AMH is a major regulator of the gonadotropic axis throughout the infantile period, leading to adult reproductive function programming<sup>(30)</sup>. A prior published study described the highest expression of AMH in small follicles as slowly disappearing from large-sized FSH-dependent follicles.

Based on the evidence currently available, it seems fair to suggest that AMH serum levels and AFCs were higher in PCOS women and associated with each other positively. This approves that a large count of small antral follicles in general, associated with the polycystic histological appearance of the ovary, is behind the raised AMH synthesis<sup>(31, 32)</sup>, a finding that agreed with the current study.

The idea that the smaller antral follicles may not always be seen by TVUS scanning and do contribute to the AMH values may help to explain some of our findings and raise questions about the role of serum AMH in PCOS diagnosis. However, additional future well-designed large cohorts could further validate the association of AMH with AFCs in PCOS.

## Conclusion

The levels of serum AMH in PCOS is intensely correlated with the status of AFCs throughout the initial follicular phase. The association is stronger than that detected with other body hormones of follicular function. Serum AMH measure in PCOS on days 2-3 of the cycle is a superior predictor of the early AFCs than traditional hormonal assays. Hence, AMH serum levels offer a good diagnostic potency in the definition of PCOS.

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