Hormonal Predictors of ICSI: AMH Versus FSH

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Abstract: _Background: Assessment of ovarian reserve is central to counselling and outcome prediction in IVF and ICSI cycles. Basal follicle-stimulating hormone (FSH) and anti-Müllerian hormone (AMH) are widely used markers, yet their relative ability to predict clinically meaningful outcomes such as live birth remains uncertain, particularly across different maternal age groups and in women with discordant hormonal profiles. Aim: To evaluate the association of basal Anti-Müllerian Hormone and Follicle-Stimulating Hormone levels with ovarian response and reproductive outcomes in women undergoing ICSI. Methods: This retrospective observational study included 127 women who underwent ICSI at Madras Medical Mission from 2020 to 2025. Participants were classified into four groups based on combined basal AMH and FSH levels like Group 1: AMH > 1 ng/mL and FSH ≤ 10 IU/mL, Group 2: AMH ≤ 1 ng/mL and FSH > 10 IU/mL, Group 3: AMH > 1 ng/mL and FSH > 10 IU/mL and Group 4: AMH ≤ 1 ng/mL and FSH ≤ 10 IU/mL. Maternal age was stratified into Group A (<35 years), Group B (35–37 years), Group C (37–40 years), and Group D (>40 years). Primary outcome was live birth rate. Secondary outcomes included antral follicle count, oocyte yield, number of mature (M2) oocytes, and clinical pregnancy rate. Group comparisons and regression analyses were performed to assess associations between hormonal markers and outcomes. Results: Women with concordantly favourable AMH and FSH levels demonstrated the highest antral follicle count, oocyte yield, and live birth rate. Significant differences were observed in oocyte yield, M2 oocytes, and live birth rate across AMH/FSH groups. Clinical pregnancy rates were higher in group with concordantly favourable AMH and FSH levels and lower in group with concordantly unfavourable AMH and FSH levels but did not differ significantly. In women younger than 35 years, multivariate analysis showed favourable basal FSH to be an independent predictor of live birth, while AMH and oocyte yield were not significant after adjustment. In women with discordant AMH and FSH profiles, AMH showed a stronger association with live birth than FSH. Conclusion: Basal FSH appears to be better predictor of live birth rate in women younger than 35 years, whereas AMH is a better predictor in women older than 35 years and with discordant hormonal profiles. Combined interpretation of AMH, FSH, and age provides a more clinically useful framework for prognostication in ICSI cycles._

Keywords: Anti-Müllerian hormone; Follicle-stimulating hormone; IVF; ICSI; Live birth rate; Ovarian reserve; Maternal age

1. Introduction

Female fertility declines with increasing age, largely due to a reduction in both the quantity and quality of oocytes(1). Assessment of ovarian reserve is therefore central to counselling and treatment planning in assisted reproductive techniques such as IVF and ICSI(2). Basal follicle-stimulating hormone (FSH) and Anti-Müllerian Hormone (AMH) are the two most commonly used biochemical markers for this purpose(3). FSH is secreted by the pituitary gland and rises as ovarian reserve diminishes, whereas AMH is produced by pre-antral and early antral follicles and reflects the remaining follicular pool(4). Although both markers are widely used, their predictive value for treatment outcomes remains debated.

AMH is considered a good predictor of antral follicle count and oocyte yield, while FSH has been linked more closely to oocyte quality. Importantly, AMH and FSH are inversely correlated, yet a substantial proportion of women show discordant values, where one marker suggests good reserve and the other suggests poor reserve(5). In such cases, clinical decision-making becomes challenging. Moreover, maternal age may modify the relationship between these hormonal markers and reproductive outcomes, including clinical pregnancy and live birth rates(6). Existing evidence is inconsistent regarding which marker is superior, particularly across different age groups and in women with discordant AMH and FSH profiles(4).

There is a need for clearer evidence on how AMH and FSH relate to meaningful clinical outcomes rather than laboratory parameters alone. Live birth rate is the most relevant endpoint for patients and clinicians, yet data comparing the predictive value of AMH and FSH for live birth across age categories are limited. Understanding the relative usefulness of these markers, especially in discordant hormonal profiles, can improve patient counselling, individualise treatment strategies, and optimise expectations from IVF/ICSI cycles.

Aim

To evaluate the association of basal AMH and FSH levels with antral follicle count, oocyte yield, mature oocyte number, clinical pregnancy rate, and live birth rate across different maternal age groups, and to determine whether AMH or FSH is a better predictor of live birth in women with discordant AMH and FSH levels.

2. Materials and Methods

This retrospective observational study was conducted to evaluate the association between basal hormonal markers and IVF/ICSI outcomes. The design enabled assessment of routinely measured hormonal parameters alongside clinical and reproductive outcomes without any modification to standard treatment protocols. The study was carried out at the Institute of Reproductive Medicine at Madras Medical Mission, Chennai, a tertiary-level referral centre offering comprehensive infertility services, including IVF and ICSI. The centre serves a heterogeneous patient population drawn from both urban and semi-urban regions. Ethical approval was obtained before initiation of the study following submission of the study protocol, data collection proforma, and measures to ensure patient confidentiality. Approval was granted by the Institutional Ethics Committee Via letter no ECR/140/Inst/TN/2013/RR-25, dated 16/6/2025 (Annexure 1). The study was conducted in accordance with the principles of the Declaration of Helsinki and the guidelines issued by the Indian Council of Medical Research. This retrospective analysis included patients treated at the study

centre between January 2020 and January 2025. The primary outcome measure was live birth rate following ICSI. Secondary outcomes included antral follicle count, total oocyte yield, number of mature (M2) oocytes, and clinical pregnancy rate. All outcomes were assessed using routinely maintained clinical, laboratory, and embryology records corresponding to each treatment cycle. The exposure of interest was basal hormonal status, defined by serum anti-Müllerian hormone and basal follicle-stimulating hormone levels measured prior to ovarian stimulation. Based on predefined AMH and FSH cut-off values, participants were categorised into specific prognostic groups as outlined in the study protocol. Study participants comprised women who underwent ICSI cycles during the study period and had complete records of basal AMH, basal FSH, and treatment outcomes.

Inclusion Criteria

- Women who underwent IVF or ICSI treatment cycles during the study period.
- Availability of documented basal serum AMH and basal FSH levels measured prior to ovarian stimulation.
- Availability of baseline antral follicle count data.
- Controlled ovarian stimulation using GnRH agonist or antagonist protocol
- Complete clinical, laboratory, and embryology records allowing assessment of oocyte yield, M2 oocytes, clinical pregnancy, and live birth outcomes.

Exclusion Criteria

- IVF/ICSI cycles with missing or incomplete AMH, FSH, or outcome data.
- Cycles cancelled before oocyte retrieval.
- Severe azoospermia
- Uterine or structural abnormalities
- Records with incomplete documentation of key study variables required for analysis.

Study Groups

Participants were categorised into four groups based on combined AMH and FSH levels:
- Group 1: AMH > 1 ng/mL and FSH ≤ 10 IU/mL
- Group 2: AMH ≤ 1 ng/mL and FSH > 10 IU/mL
- Group 3: AMH > 1 ng/mL and FSH > 10 IU/mL
- Group 4: AMH ≤ 1 ng/mL and FSH ≤ 10 IU/mL

Allocation to study groups was carried out retrospectively based on recorded basal hormonal values, and no randomisation or active intervention was involved in the grouping process. All eligible individuals attending the facility during the study period who met the selection criteria were included, resulting in a final sample size of 127 participants. Convenience sampling was adopted, as all eligible IVF/ICSI cycles performed during the defined study period were analysed. This sampling approach was considered appropriate in view of the retrospective design and the clearly defined study population.Potential participants were identified from Assisted Reproductive Technology unit records by the Principal Investigator. Eligibility was determined using the predefined inclusion and exclusion criteria, and only records with complete and verifiable data were included in the analysis. As the study was retrospective and record-based, informed consent

procedures were conducted in accordance with institutional policy. Patient confidentiality was strictly maintained throughout the study, and no direct contact with participants occurred during data collection or data extraction

a) **Data Collection Tool:** A close-ended data collection proforma was developed through a structured process involving literature review, identification of relevant variables, review by the study supervisor and departmental faculty, and pilot testing followed by refinement and finalisation.

b) **Data Quality Assurance:** Data accuracy was ensured through cross-verification of records by the Principal Investigator under the supervision of the study supervisor. Periodic reviews were conducted to minimise entry errors.All extracted data were anonymised prior to entry into electronic databases. Physical records remained secured within the department. Electronic data were password protected and accessed only by the investigators.

c) **Data Collection Procedure:** Data collection was undertaken by us under the guidance of the Study Supervisor and in accordance with the protocol approved by the Institutional Ethics Committee. Eligible ICSI cycles were identified from ART unit registers. Hormonal values, clinical parameters, and outcomes were extracted systematically using the pre-designed proforma. Data were cross-checked against source records before entry into the electronic database. Data entry was performed in batches with periodic verification to ensure accuracy and completeness.

Study Variables

Dependent Variables
- Live birth rate
- Clinical pregnancy rate

Independent Variables
- Basal AMH
- Basal FSH

Confounding Variables
- Maternal age

Statistical Analysis: The primary hypothesis tested whether AMH or FSH better predicted live birth across maternal age groups and discordant hormonal profiles. Continuous variables were summarised using means and standard deviations, while categorical variables were expressed as proportions. Group comparisons were performed using appropriate parametric or non-parametric tests. Associations between hormonal markers and outcomes were assessed using regression analysis. Both statistical and graphical analyses were conducted using Stata version 17.0.

3. Results

A total of 127 women undergoing IVF/ICSI were included in the analysis and were categorised into four groups based on combined basal AMH and FSH levels. The majority of participants belonged to Group 1, defined by AMH levels greater than 1 ng/mL and FSH levels of 10 mIU/mL or less, comprising 81 women (63.8%). Group 3, characterised by

AMH levels of at least 1 ng/mL with elevated FSH levels above 10 mIU/mL, accounted for 21 participants (16.5%). Group 4, with both AMH at or below 1 ng/mL and FSH at or below 10 mIU/mL, included 15 women (11.8%). The smallest proportion was observed in Group 2, representing women with low AMH and elevated FSH levels, with 10 participants (7.9%). This distribution indicates that nearly two-thirds of the study population demonstrated a hormonally favourable profile, while a smaller subset exhibited discordant or unfavourable AMH and FSH patterns.

Participants were stratified into four maternal age categories to examine age-wise distribution within the study cohort. Women younger than 35 years constituted the largest group, with 64 participants, accounting for 50.4% of the total sample. This was followed by the 35–37 years age group, which included 39 women (30.7%). The 37–40 years category comprised 18 participants, representing 14.2% of the cohort. Women older than 40 years formed the smallest group, with 6 participants, contributing 4.7% of the study population.

The association between AMH/FSH groups and reproductive outcomes is summarised in Table 1. Significant differences were observed in both oocyte yield and number of mature (M2) oocytes across the four groups. Group 1 demonstrated the highest mean number of oocytes retrieved (15.07 ± 8.56), while Group 2 showed the lowest yield (6.40 ± 3.60), and this difference was statistically significant (F = 11.12, p < .001). A similar pattern was noted for M2 oocytes, with Group 1 recording the highest mean count (11.26 ± 5.81) and Group 2 the lowest (4.47 ± 2.03), again reaching statistical significance (F = 9.75, p < .001).

Clinical pregnancy rates were high across all groups, ranging from 80.0% to 95.2%. Group 3 had the highest clinical pregnancy rate (95.2%), followed by Group 1 (90.1%), Group 4 (86.7%), and Group 2 (80.0%). However, these differences were not statistically significant (χ^2 = 2.47, p = .481). In contrast, live birth rates differed significantly among the groups (χ^2 = 8.12, p = .044). Group 1 had the highest live birth rate at 56.8%, closely followed by Group 3 at 52.4%. Lower live birth rates were observed in Group 4 (40.0%) and Group 2 (20.0%).

Table 1: Association of Oocyte Yield, M2 Oocytes, CPR, and LBR with AMH/FSH Groups

Variable	Group 1 (n = 81)	Group 2 (n = 10)	Group 3 (n = 21)	Group 4 (n = 15)	p-value
Oocytes Collected (M ± SD)	15.07 ± 8.56	6.40 ± 3.60	14.24 ± 8.14	7.50 ± 4.60	< .001
M2 Oocytes (M ± SD)	11.26 ± 5.81	4.47 ± 2.03	10.76 ± 5.87	5.40 ± 2.46	< .001
CPR (n, %)	73 (90.1%)	8 (80.0%)	20 (95.2%)	13 (86.7%)	.481
LBR (n, % with ≥ 1)	46 (56.8%)	2 (20.0%)	11 (52.4%)	6 (40.0%)	.044

Table 2: Association of Basal FSH with Delivery Rate by Maternal Age Category

Age Category	FSH ≤ 10 (n, % LBR ≥ 1)	FSH > 10 (n, % LBR ≥ 1)	p-value
Group A (< 35)	36/60 (60.0%)	2/4 (50.0%)	.626
Group B (35–37)	13/28 (46.4%)	7/11 (63.6%)	.368
Group C (37–40)	6/13 (46.2%)	3/5 (60.0%)	.592
Group D (> 40)	1/3 (33.3%)	2/3 (66.7%)	.414

The association between basal FSH levels and delivery rates across different maternal age categories is presented in Table 2. Among women younger than 35 years, those with favourable basal FSH levels (≤ 10 mIU/mL) had a delivery rate of 60.0%, compared with 50.0% in women with elevated FSH levels. This difference, however, was not statistically significant (χ^2 = 0.24, p = .626).

In women aged 35–37 years, the delivery rate was 46.4% in those with favourable FSH levels, while a higher delivery rate of 63.6% was observed among women with unfavourable FSH levels. This difference did not reach statistical significance (χ^2 = 0.81, p = .368). A similar pattern was seen in the 37–40 years age group, where delivery rates were 46.2% in women with favourable FSH and 60.0% in those with elevated FSH levels, with no significant association (χ^2 = 0.29, p = .592). Among women older than 40 years, delivery occurred in 33.3% of those with favourable FSH levels and in 66.7% of those with elevated FSH levels. This difference was also not statistically significant (χ^2 = 0.67, p = .414). Overall, basal FSH levels alone did not show a statistically significant association with delivery rates across any maternal age category.

Table 3: Univariate Analysis of AMH, FSH, and Oocyte Yield with Live Birth Rate by Age Category

Age Category	Predictor	OR	95% CI	p-value
Group A (< 35)	Favorable AMH	3.00	0.68, 13.23	.146
	Favorable FSH	1.50	0.19, 11.85	.696
	High Oocyte Yield	2.80	1.02, 7.67	.046
Group B (35–37)	Favorable AMH	2.25	0.56, 9.03	.251
	Favorable FSH	0.56	0.14, 2.23	.412
	High Oocyte Yield	2.40	0.67, 8.59	.181
Group C (37–40)	Favorable AMH	3.00	0.45, 20.00	.256
	Favorable FSH	0.60	0.09, 4.00	.603
	High Oocyte Yield	3.50	0.53, 23.06	.196
Group D (> 40)	Favorable AMH	2.00	0.15, 26.67	.589
	Favorable FSH	0.50	0.04, 6.67	.599
	High Oocyte Yield	2.50	0.19, 33.33	.484

The univariate analysis examining the association of AMH, FSH, and oocyte yield with live birth rate across maternal age categories is summarised in Table 3. Among women younger than 35 years, favourable AMH levels were associated with higher odds of live birth, although this did not reach statistical significance (OR = 3.00, 95% CI: 0.68–13.23; p = .146). Favourable FSH levels also showed no significant association with live birth in this age group (OR = 1.50, 95% CI: 0.19–11.85; p = .696). In contrast, higher oocyte yield was significantly associated with increased odds of live birth in women below 35 years (OR = 2.80, 95% CI: 1.02–7.67; p = .046).

In women aged 35–37 years, favourable AMH levels were associated with higher odds of live birth, though the association was not statistically significant (OR = 2.25, 95% CI: 0.56–9.03; p = .251). Favourable FSH levels showed lower odds of live birth in this group, but without statistical

significance (OR = 0.56, 95% CI: 0.14–2.23; p = .412). Higher oocyte yield also did not show a significant association with live birth (OR = 2.40, 95% CI: 0.67–8.59; p = .181).Similar trends were observed in women aged 37–40 years, where favourable AMH levels (OR = 3.00, 95% CI: 0.45–20.00; p = .256) and higher oocyte yield (OR = 3.50, 95% CI: 0.53–23.06; p = .196) showed increased odds of live birth without statistical significance. Favourable FSH levels were not associated with live birth in this group (OR = 0.60, 95% CI: 0.09–4.00; p = .603).

Table 4: Multivariate Analysis of FSH, AMH, and Oocyte Yield with Live Birth Rate in women less than 35 years

Predictor	OR	95% CI	p-value
Favorable FSH	4.20	1.05, 16.80	.042
Favorable AMH	2.00	0.43, 9.30	.372
High Oocyte Yield	1.85	0.63, 5.4	.265

The multivariate analysis evaluating predictors of live birth in women younger than 35 years is presented in Table 4, favourable basal FSH levels (≤ 10 mIU/mL) emerged as a significant independent predictor of live birth. Women with favourable FSH had more than fourfold higher odds of achieving a live birth compared with those with elevated FSH levels (OR = 4.20, 95% CI: 1.05–16.80; p = .042). In contrast, favourable AMH levels did not show a statistically significant association with live birth in the adjusted model (OR = 2.00, 95% CI: 0.43–9.30; p = .372). Similarly, higher oocyte yield was not independently associated with live birth after adjustment for hormonal parameters (OR = 1.85, 95% CI: 0.63–5.43; p = .265). These findings indicate that, in woman younger than 35 years, basal FSH was a stronger predictor of live birth than AMH or oocyte yield when considered concurrently.

Among the discordant group, favourable AMH levels (≥ 1 ng/mL) were associated with higher odds of achieving a live birth compared with unfavourable AMH levels. In univariate analysis, AMH showed an odds ratio of 2.67, although this association did not reach statistical significance. In contrast, favourable basal FSH levels demonstrated lower odds of live birth, with no significant association. When both markers were included in a multivariate model, AMH remained a stronger predictor of live birth than FSH; however, neither marker achieved statistical significance, likely due to the limited sample size within the discordant subgroup. Overall, these findings suggest a trend towards AMH being a more informative marker than FSH for live birth prediction in women with discordant AMH and FSH profiles.

Women younger than 35 years had the highest mean antral follicle count. A progressive decline in antral follicle count was observed with increasing age across the successive age categories of 35–37 years, 37–40 years, and above 40 years. This downward trend was statistically significant, indicating a clear association between advancing maternal age and reduced follicular reserve. Women with concordantly favourable hormonal profiles demonstrated the highest mean antral follicle count. In contrast, those with concordantly unfavourable AMH and FSH levels exhibited the lowest follicular counts. The two discordant groups showed intermediate antral follicle counts, with women having preserved AMH despite elevated FSH retaining a relatively

higher follicular reserve than those with low AMH but normal FSH. The differences in antral follicle count across the four hormonal groups were highly statistically significant, underscoring the strong relationship between combined hormonal status and ovarian reserve.

4. Discussion

The present study compared basal AMH and basal FSH as predictors of ICSI outcomes, with a focus on live birth and the special scenario of discordant AMH–FSH profiles. Overall, the cohort showed clear separation of ovarian response across the four AMH/FSH categories. Women in the concordantly favourable group (AMH >1 ng/mL and FSH ≤10 mIU/mL) had the highest oocyte yield and M2 oocyte numbers, and also achieved the best live birth rate, while the concordantly unfavourable group (AMH ≤1 ng/mL and FSH >10 mIU/mL) had the lowest oocyte yield and the lowest live birth rate. This pattern is biologically plausible because AMH reflects follicular pool size and is strongly linked to ovarian response, while elevated FSH is a feature of diminished reserve.

The strong relationship between AMH/FSH grouping and ovarian response in the present study is consistent with prior evidence that AMH is a reliable quantitative marker of ovarian reserve. Large dataset work by Wang et al. found that AMH had stronger predictive value than FSH for live birth, and they emphasised its usefulness when AMH and FSH are discordant (7).

In this study, women with concordantly favourable AMH and FSH levels demonstrated the highest antral follicle count, oocyte yield, number of mature oocytes, and live birth rate. This observation aligns with earlier reports showing that combined interpretation of AMH and FSH provides a more accurate reflection of ovarian reserve than either marker alone. Gleicher et al. reported that concordant AMH–FSH profiles are clinically meaningful and superior to isolated hormone values in predicting IVF outcomes, supporting the present findings(8).

Among the study participant, AMH showed a strong association with antral follicle count and oocyte yield, which is consistent with multiple studies identifying AMH as a robust quantitative marker of ovarian reserve. La Marca and colleagues, as well as Wang et al., demonstrated that AMH correlates closely with follicular pool size and ovarian response, but its relationship with live birth is less consistent(7,9). The present study supports this pattern, showing that although AMH predicted oocyte yield effectively, its independent association with live birth was weaker, particularly in younger women.

A key finding of this study is the age-dependent role of basal FSH. In women younger than 35 years, favourable basal FSH emerged as an independent predictor of live birth after multivariate adjustment, whereas AMH did not. This supports the concept that FSH may reflect oocyte competence rather than quantity, as suggested by Buratini et al., who proposed that FSH is linked to follicular sensitivity and developmental competence(10). Similar age-specific relevance of FSH has been reported by Salama et al., who

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found basal FSH to be more informative in younger women undergoing ICSI(11). In contrast, among women with age more than 35 years and those with discordant AMH and FSH profiles, AMH appeared to be a stronger predictor of live birth than FSH, although statistical significance was limited by sample size. These findings are in agreement with studies by Wang et al. and Ligon et al., which showed that in discordant cases, AMH was superior to FSH in predicting live birth(7,12). This suggests that in older women, where follicular depletion predominates, AMH may better capture residual reproductive potential.

Clinical pregnancy rates were high across all groups and did not differ significantly, indicating that differences in live birth were likely influenced by post-implantation factors, embryo competence, or endometrial receptivity rather than fertilisation alone. The progressive decline in antral follicle count with advancing age observed in this study is consistent with well-established biological trends and reinforces the importance of age as a central confounder in ovarian reserve assessment.

Overall, the present findings support a nuanced, age-specific interpretation of ovarian reserve markers. Reliance on a single hormone may be misleading, particularly in discordant profiles. The combined use of AMH, basal FSH, and antral follicle count, interpreted in the context of maternal age, offers a more clinically relevant framework for counselling, prognosis, and individualised treatment planning in IVF/ICSI.

A key contribution of the present study is the age-stratified interpretation of these markers. In women younger than 35 years, multivariable modelling showed that favourable basal FSH independently predicted live birth, whereas AMH was not significant after adjustment. This agrees closely with Salama et al., who reported that below 35 years, pregnancy chance is more correlated with FSH, while above 35 years AMH becomes the more relevant test(11). The present findings therefore support the concept that, in younger women, basal FSH may capture elements of follicular function or oocyte competence that are not fully explained by AMH alone.

Taken together, the present findings are aligned with the broader evidence base: AMH is a strong marker for ovarian response and tends to outperform FSH in discordant profiles and older women, while basal FSH may retain independent prognostic value for live birth in women below 35 years. Clinically, this supports an age-specific approach to interpretation. In younger patients, a "reassuring" FSH may carry meaningful prognostic information even when AMH is lower, while in older patients and discordant cases, AMH may better reflect remaining reproductive potential and expected yield.

5. Conclusion

This study demonstrates that basal AMH and FSH provide complementary, rather than interchangeable, information in the assessment of reproductive potential in women undergoing IVF/ICSI. Women with concordantly favourable AMH and FSH levels showed superior ovarian response and

the highest live birth rates, confirming the clinical relevance of combined hormonal assessment. Although AMH was strongly associated with antral follicle count and oocyte yield, its ability to independently predict live birth was influenced by maternal age.

In women younger than 35 years, basal FSH emerged as an independent predictor of live birth after adjustment for AMH and oocyte yield, suggesting that FSH may better reflect oocyte competence in this age group. In contrast, among women of advanced maternal age and those with discordant AMH and FSH profiles, AMH showed a relatively stronger association with live birth and oocyte yield than FSH, although statistical significance was limited by smaller subgroup sizes. Clinical pregnancy rates remained high across all hormonal profiles, indicating that differences in live birth were more closely related to post-implantation factors than to conception alone.

Conflict of Interest: The authors declare no conflicts of interest in the design, implementation, or interpretation of this study.

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