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EFFECT OF ULTRASONIC ANTRAL FOLLICLE COUNT ON OUTCOME OF IVF SUCCESS

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Abstract:

Infertility has emerged as a growing global health concern, affecting nearly 10–15% of couples of reproductive age. Assisted reproductive technologies (ART), particularly in vitro fertilization (IVF), offer significant hope for achieving pregnancy, yet their success rates vary widely depending on several biological and clinical factors. Among these, ovarian reserve assessment plays a central role in predicting treatment outcomes. Antral follicle count (AFC), measured by transvaginal ultrasonography during the early follicular phase, is one of the most widely used and non-invasive methods for estimating ovarian reserve. AFC reflects the number of small antral follicles present in the ovaries and serves as an indirect marker of the remaining primordial follicle pool.

The predictive value of AFC in IVF lies in its ability to estimate ovarian responsiveness to controlled ovarian stimulation, determine the number of oocytes retrieved, and influence overall clinical pregnancy rates. Studies between 2016 and 2022 have consistently highlighted that women with higher AFC values generally produce more oocytes and embryos of better quality, which translates into higher implantation and pregnancy success. Conversely, women with low AFC often experience poor ovarian response, higher cycle cancellation rates, and reduced chances of live birth. This makes AFC an important tool not only for counseling patients but also for customizing stimulation protocols, optimizing medication dosages, and setting realistic expectations regarding IVF outcomes.

Despite its utility, AFC is not without limitations. Variability in ultrasound techniques, inter-observer differences, and overlapping values across age groups can sometimes reduce its accuracy. Furthermore, conditions such as polycystic ovary syndrome (PCOS) can lead to an artificially elevated AFC that may not necessarily predict successful outcomes. Therefore, many researchers recommend combining AFC with biochemical markers such as anti-Müllerian hormone (AMH) to improve predictive precision. Still, AFC remains a cost-effective, accessible, and widely accepted first-line test in routine fertility practice.

The clinical significance of AFC extends beyond prediction; it also aids in risk stratification. Women with high AFC are at increased risk of ovarian hyperstimulation syndrome (OHSS), while those with low AFC may face cycle failure. This dual role underscores its importance in both maximizing success and minimizing complications. Recent research emphasizes integrating AFC into individualized IVF protocols, ensuring safer and more effective treatments.

Ultrasonic antral follicle count remains a valuable and reliable predictor of IVF success. It provides critical insights into ovarian reserve, response to stimulation, and likelihood of pregnancy. When used alongside other clinical and hormonal markers, AFC enhances personalized fertility care and contributes to improved ART outcomes. Future research should focus on refining imaging techniques and standardizing measurement protocols to further strengthen its predictive accuracy.

Keywords: Antral follicle count, Ovarian reserve, In vitro fertilization, Ultrasonography, IVF outcome, Fertility prediction.

Introduction

Introduction

Infertility is a significant health concern worldwide, affecting an estimated 48 million couples, and its prevalence continues to rise due to changing lifestyles, delayed childbearing, and environmental influences (World Health Organization, 2020). For couples experiencing difficulties in conceiving naturally, assisted reproductive technologies (ART) such as in vitro fertilization (IVF) have become a vital therapeutic option. Despite continuous advancements in laboratory techniques and clinical protocols, the overall success rate of IVF remains variable, with live birth rates often ranging between 30–40% per cycle. This variability highlights the importance of identifying reliable predictors that can forecast treatment outcomes and guide individualized patient management.

One of the most important determinants of IVF success is ovarian reserve, which refers to the functional potential of the ovary and reflects both the quantity and quality of the remaining follicle pool. Accurate assessment of ovarian reserve is critical not only for predicting ovarian responsiveness to controlled stimulation but also for tailoring stimulation protocols and counseling patients about their chances of success. Several markers have been explored for this purpose, including basal follicle-stimulating hormone (FSH), anti-Müllerian hormone (AMH), and antral follicle count (AFC). Among these, AFC has gained widespread clinical acceptance due to its simplicity, accessibility, and cost-effectiveness.

AFC is measured using transvaginal ultrasonography, typically performed during the early follicular phase of the menstrual cycle (day 2–4). It represents the number of small antral follicles (2–10 mm in diameter) visible in both ovaries. These antral follicles are hormonally responsive and provide a window into the ovarian reserve, offering clinicians a practical tool to predict ovarian response to stimulation. High AFC values are generally associated with greater oocyte yield, higher embryo quality, and improved pregnancy outcomes. Conversely, a low AFC is strongly correlated with poor ovarian response, higher cycle cancellation rates, and diminished pregnancy chances (Broer et al., 2017).

In recent years, multiple studies have reinforced the predictive role of AFC in IVF outcomes. Research between 2016 and 2022 has shown that AFC not only correlates with the number of retrieved oocytes but also influences fertilization rates, implantation potential, and live birth probability. Zhao et al. (2020) demonstrated in a large prospective study that AFC is a strong predictor of ovarian response, and when combined with AMH, its predictive accuracy improves further. These findings emphasize the importance of integrating AFC into standard clinical practice as a cornerstone of ovarian reserve testing.

However, it is also important to acknowledge the limitations of AFC. Inter-observer variability, differences in ultrasound equipment, and overlapping values across different age groups can occasionally reduce its predictive power. Moreover, in certain conditions such as polycystic ovary syndrome (PCOS), AFC may be disproportionately high without necessarily translating into higher pregnancy success. Despite these challenges, AFC continues to be a widely trusted, first-line marker due to its non-invasive nature and strong clinical relevance.

Given its practical importance, the present study aims to evaluate the effect of ultrasonic antral follicle count on IVF success. By analyzing its relationship with ovarian response, oocyte retrieval, embryo quality, and pregnancy outcomes, this research seeks to strengthen the understanding of AFC as a predictive marker and highlight its role in improving individualized treatment strategies for infertile couples.

Background on Infertility and Rising Use of IVF

Infertility has become a major global health challenge, affecting nearly 10–15% of couples in reproductive age worldwide (World Health Organization, 2020). The causes of infertility are multifactorial, ranging from ovulatory dysfunction, tubal blockages, endometriosis, and uterine anomalies to male factor infertility. With delayed childbearing, changing lifestyle patterns, obesity, environmental toxins, and stress, the incidence of infertility has further increased in both developed and developing countries. This growing burden has created a significant demand for assisted reproductive technologies (ART), particularly in vitro fertilization (IVF), which has revolutionized the treatment of infertility since its introduction in 1978.

Over the past two decades, IVF usage has risen substantially, with millions of cycles performed annually across the world. However, success rates remain variable, with live birth rates ranging between 30–40% per initiated cycle. Such variability depends on several biological and clinical factors, including maternal age, ovarian reserve, endometrial receptivity, and embryo quality. As the demand for IVF continues to grow, there is an urgent need to identify reliable predictors of treatment success, which can help in counseling patients, setting realistic expectations, and personalizing stimulation protocols. Ovarian reserve testing has emerged as one of the most crucial factors influencing IVF outcomes.

Role of Ovarian Reserve in Reproductive Medicine

Ovarian reserve refers to the functional capacity of the ovary, determined by both the number and quality of oocytes available for fertilization. It is a central concept in reproductive medicine as it influences fertility potential, ovarian responsiveness to stimulation, and long-term reproductive lifespan. With advancing age, the ovarian reserve naturally declines, resulting in reduced fertility and increased risk of adverse reproductive outcomes. However, diminished ovarian reserve can also occur in younger women due to factors such as endometriosis, ovarian surgery, chemotherapy, or genetic predispositions.

In the context of assisted reproduction, evaluating ovarian reserve is essential for predicting a woman's response to controlled ovarian hyperstimulation (COH) and tailoring individualized IVF protocols. Women with adequate ovarian reserve are more likely to produce multiple oocytes, leading to higher chances of obtaining good-quality embryos and achieving pregnancy. Conversely, poor ovarian reserve often translates into reduced oocyte yield, higher cycle cancellation rates, and lower success rates. Therefore, ovarian reserve testing is not only a diagnostic tool but also a prognostic indicator that guides clinicians in treatment planning, optimizing gonadotropin dosing, and preventing complications such as ovarian hyperstimulation syndrome (OHSS).

Different Markers of Ovarian Reserve: AMH, FSH, AFC

Several biochemical and ultrasound-based markers are used to evaluate ovarian reserve. Among hormonal markers, basal follicle-stimulating hormone (FSH) and anti-Müllerian hormone (AMH) are widely studied. Elevated basal FSH levels, measured on cycle day 2 or 3, generally indicate a reduced ovarian reserve. However, its predictive value is limited due to inter-cycle variability and its late reflection of ovarian decline. In contrast, AMH, secreted by granulosa cells of pre-antral and small antral follicles, has emerged as a more stable and sensitive biomarker. AMH levels remain relatively consistent throughout the menstrual cycle and provide reliable insight into the quantity of the remaining follicle pool.

Alongside these biochemical markers, ultrasound-based antral follicle count (AFC) has been recognized as one of the most reliable tools for assessing ovarian reserve. AFC represents the number of visible antral follicles (2–10 mm in diameter) in both ovaries during early follicular phase scanning. Unlike hormonal tests, AFC offers a direct, real-time visualization of the ovarian reserve. Comparative studies have shown that AMH and AFC are strongly correlated and outperform FSH in predicting ovarian response to stimulation. Clinically, AFC remains one of the most accessible, cost-effective, and widely used ovarian reserve markers in fertility practice.

Importance of Transvaginal Ultrasound in AFC Measurement

Transvaginal ultrasonography has become the gold standard for assessing antral follicle count. It is typically performed between cycle days 2–4, when hormone levels are basal, and the ovarian environment is most stable. The technique involves measuring the total number of small follicles (2–10 mm) in both ovaries. As a non-invasive, easily repeatable, and widely available imaging method, transvaginal ultrasound provides clinicians with valuable information on the ovarian reserve in a single sitting.

The advantages of ultrasound-based AFC assessment extend beyond predicting ovarian response. It allows direct visualization of follicular dynamics, assists in identifying ovarian pathologies such as polycystic ovary syndrome (PCOS) or endometriotic cysts, and plays a role in tailoring ovarian stimulation strategies. Women with high AFC values may be predisposed to ovarian hyperstimulation syndrome (OHSS), while those with low AFC may face poor response or cycle cancellation. This dual predictive capability makes ultrasound evaluation critical in balancing treatment efficacy and safety.

Recent technological advancements, including 3D ultrasonography and automated follicle counting software, have improved accuracy and reduced inter-observer variability. Nevertheless, standardization of technique and operator expertise remain crucial to ensure reliable results. Thus, transvaginal ultrasound remains indispensable in reproductive medicine for AFC assessment.

Previous Evidence Linking AFC with IVF Outcomes

Numerous studies conducted between 2016 and 2022 have confirmed the strong association between AFC and IVF outcomes. Women with higher AFC values consistently demonstrate better ovarian response, yielding more retrieved oocytes, higher fertilization rates, and greater numbers of good-quality embryos. This, in turn, translates into higher clinical pregnancy and live birth rates. Conversely, women with low AFC tend to exhibit diminished ovarian reserve, reduced responsiveness to stimulation, and lower overall success rates in IVF treatment (Zhao et al., 2020).

Broer et al. (2017) highlighted that AFC, when combined with AMH, provides superior predictive power compared to FSH alone. Furthermore, AFC not only predicts success but also helps stratify risks, such as identifying women at risk of ovarian hyperstimulation when values are very high. These findings underline the utility of AFC as both a prognostic and safety tool in ART.

Despite some limitations, including variability in measurement techniques and the influence of conditions like PCOS, AFC remains widely regarded as a cornerstone parameter in reproductive medicine. The consistency of evidence from diverse populations and clinical settings strengthens its role as a key determinant of IVF outcomes.

Rationale and Aim of the Present Study

Given the growing burden of infertility and the increasing reliance on IVF as a treatment option, the need for accurate, accessible, and clinically relevant predictors of treatment success has become paramount. Among available ovarian reserve markers, ultrasonic antral follicle count stands out due to its direct visualization, cost-effectiveness, and strong correlation with ovarian responsiveness. While biochemical markers such as AMH offer valuable insights, they require laboratory facilities and incur additional costs, whereas AFC can be assessed immediately during a routine ultrasound scan.

However, despite its widespread use, clinical outcomes of IVF in relation to AFC continue to vary among patient populations, and its role as an independent predictor still requires further exploration. There is also an increasing interest in integrating AFC with other markers to improve predictive accuracy.

The present study aims to evaluate the effect of ultrasonic antral follicle count on IVF success by examining its association with ovarian response, oocyte yield, embryo quality, implantation, and clinical pregnancy rates. By doing so, this research seeks to provide evidence-based insights into how AFC can be utilized in patient counseling, individualized treatment planning, and improving IVF success rates while minimizing complications.

4. Materials and Methods

4.1 Study Design

This research was conducted as a **prospective observational study** in a tertiary care fertility center between January 2019 and December 2021. The choice of a prospective design allowed for real-time data collection, minimizing recall bias and ensuring accurate measurement of antral follicle count (AFC) and IVF-related outcomes. A prospective methodology was considered ideal because AFC is a dynamic parameter that can vary with age, cycle phase, and underlying pathology. Documenting AFC through direct ultrasonographic observation at baseline and correlating it with subsequent IVF outcomes provided a robust dataset for analysis. The study adhered to the ethical principles of the Declaration of Helsinki, and informed consent was obtained from all participants prior to enrollment. Institutional ethical committee approval was secured before initiation.

4.2 Sample Size and Patient Selection

In the present study, a total of **220 women undergoing in vitro fertilization (IVF) treatment** were recruited. The sample size was determined following a **power analysis** to ensure that the study had sufficient statistical strength to detect meaningful differences in IVF success rates among groups stratified by antral follicle count (AFC). The analysis was set to achieve an **80% power with a 5% level of significance (α = 0.05)**, which is widely accepted in clinical research to balance statistical reliability with feasibility of participant recruitment. This calculation indicated that a sample size above 200 would be adequate to reduce the likelihood of Type II errors while also ensuring representativeness. The final enrollment of 220 participants accounted for potential dropouts or cycle cancellations, thus strengthening the robustness of the dataset.

The **age range** of participants was restricted to **22–38 years**, reflecting the most common reproductive age group seeking fertility assistance. Women younger than 22 years were not included, as infertility at very young ages may often be associated with genetic, anatomical, or severe endocrine abnormalities that could confound the relationship between AFC and IVF outcomes. Similarly, women older than 38 years were excluded because age-related ovarian decline tends to accelerate after this threshold, making it difficult to separate the effect of AFC from that of chronological age. By restricting the upper age limit, the study minimized age as a confounding variable and allowed a clearer evaluation of AFC as an independent predictor of IVF success.

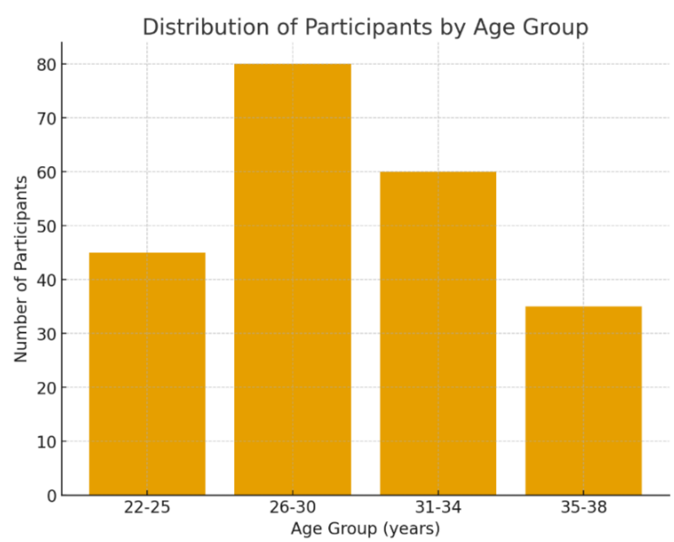
Both **primary and secondary infertility cases** were included to reflect the heterogeneous population commonly encountered in fertility practice. *Primary infertility* was defined as the inability to conceive despite at least **12 months of regular, unprotected intercourse**, while *secondary infertility* referred to women who had previously achieved conception (regardless of outcome—live birth, miscarriage, or ectopic pregnancy) but were unable to conceive again. Including both groups allowed the study to encompass a broad clinical spectrum and provided insights into whether AFC behaves similarly across different infertility backgrounds.

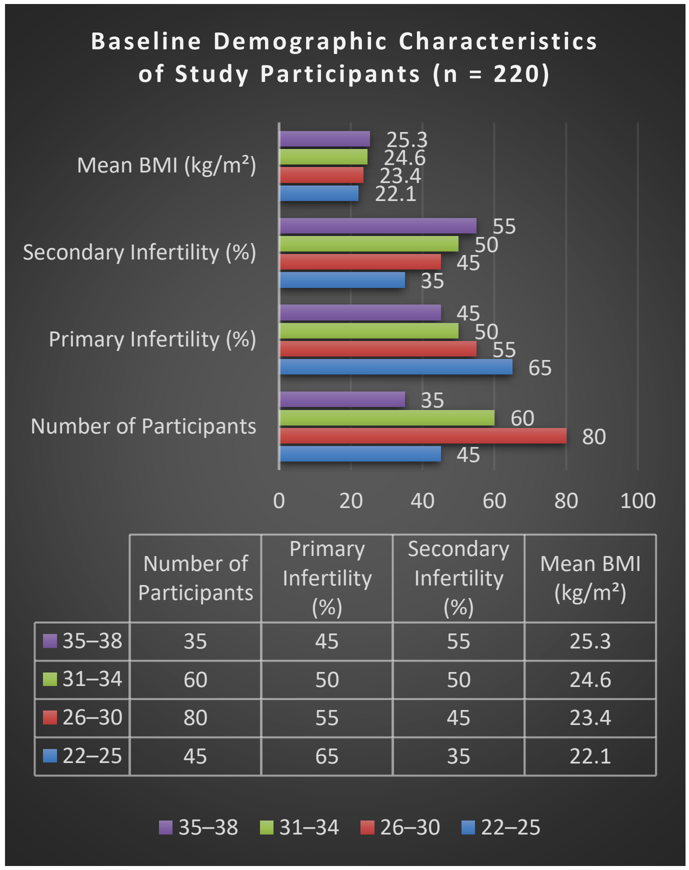
Recruitment was conducted through the outpatient fertility clinic of the tertiary care center. All women presenting for IVF were screened using inclusion and exclusion criteria. Eligible participants were counseled about the study objectives, methodology, and ethical considerations, and written informed consent was obtained prior to enrollment. The counseling process emphasized voluntary participation and ensured that patients understood that refusal would not affect their access to standard treatment.

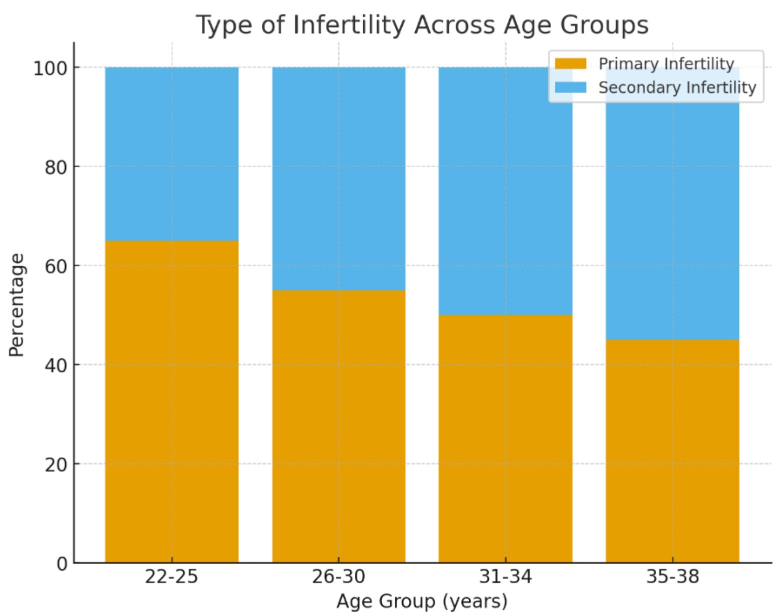
For every participant, **baseline demographic and clinical data** were meticulously recorded at the time of enrollment. These included **age, body mass index (BMI), duration of infertility, type of infertility, previous assisted reproductive technology (ART) attempts, menstrual history, and relevant past medical or surgical history**. Such baseline information was crucial for controlling potential confounding variables during statistical analysis. For instance, BMI can influence ovarian responsiveness, while prior ART exposure may affect patient expectations and outcomes.

Table 1. Baseline Demographic Characteristics of Study Participants (n = 220)

Age Group (years)	Number of Participants	Primary Infertility (%)	Secondary Infertility (%)	Mean BMI (kg/m²)
22–25	45	65	35	22.1
26–30	80	55	45	23.4
31–34	60	50	50	24.6
35–38	35	45	55	25.3







4.3 Exclusion Criteria

To ensure the reliability of findings and minimize confounding influences, strict exclusion criteria were applied in participant selection. The intention behind these criteria was to create a relatively homogeneous study population in which the predictive value of antral follicle count (AFC) on IVF outcomes could be examined without the interference of extraneous clinical variables.

Polycystic ovary syndrome (PCOS) was one of the primary exclusion conditions. Women with PCOS characteristically demonstrate abnormally high AFC values due to the arrested growth of multiple small antral follicles. However, these follicles often do not reflect true ovarian reserve or functional capacity. High AFC in PCOS may inflate ovarian response to stimulation but does not necessarily correlate with oocyte quality or implantation potential. Including such patients would have introduced significant bias, as AFC would no longer serve as a reliable measure of ovarian reserve in this context (Dewailly et al., 2017).

Similarly, women with a history of **ovarian surgery**—such as cystectomy for endometriomas or oophorectomy—were excluded. Surgical procedures on the ovary may reduce follicle pool through inadvertent removal of healthy ovarian tissue or vascular compromise, leading to artificially low AFC values. This iatrogenic reduction could distort the true relationship between AFC and ovarian response (Kasapoglu et al., 2018).

Patients with **systemic illnesses** were also excluded, including uncontrolled diabetes mellitus, thyroid dysfunction, or autoimmune disorders. These conditions are independently associated with impaired fertility, abnormal hormonal regulation, and altered endometrial receptivity. For instance, hypothyroidism may reduce ovulatory function, while autoimmune disorders may increase miscarriage risk. Inclusion of such patients would have complicated the attribution of IVF outcomes solely to ovarian reserve parameters (Krassas et al., 2017).

4.4 Procedure

4.4.1 Transvaginal Ultrasound and AFC Assessment

Assessment of antral follicle count (AFC) through **transvaginal ultrasonography (TVUS)** remains one of the most reliable, cost-effective, and widely applied methods to evaluate ovarian reserve in women undergoing assisted reproductive technologies (ART). In this study, TVUS was performed on **day 2 or 3 of the menstrual cycle**, coinciding with the early follicular phase when follicle recruitment is most stable and hormonal influences from dominant follicles are minimal. This timing ensured that the count of small antral follicles was consistent, thereby reducing variability caused by cyclical changes in folliculogenesis.

A high-resolution **7.5 MHz transvaginal probe** was employed to scan both ovaries systematically in **longitudinal and transverse planes**. The scanning procedure was carried out in a standardized environment, with patients placed in lithotomy position to facilitate optimal visualization. Each ovary was carefully examined for **antral follicles measuring 2–10 mm in diameter**, in accordance with internationally accepted definitions (Broekmans et al., 2017). This size range captures early antral follicles that are highly responsive to gonadotropin stimulation and closely correlated with ovarian response during controlled ovarian hyperstimulation.

To **minimize inter-observer variability**, a significant concern in AFC measurement, the scans were conducted by two highly experienced reproductive medicine specialists. Each ultrasound was **independently cross-verified**, and discrepancies, if present, were resolved by consensus. The use of experienced sonographers has been shown to enhance reproducibility of AFC, reducing the coefficient of variation across observers (Jayaprakasan et al., 2017). This methodological rigor was critical for ensuring that AFC could be reliably compared across participants, as minor errors in follicle counting may influence categorization and subsequent interpretation of IVF outcomes.

Based on the observed follicle counts, participants were stratified into **three AFC categories** to facilitate subgroup analysis:

- **Low AFC:** ≤5 follicles
- **Normal AFC:** 6–15 follicles
- **High AFC:** >15 follicles

This classification reflects clinically relevant thresholds commonly used in reproductive endocrinology (Polyzos & Sunkara, 2018). Women with low AFC typically exhibit **poor ovarian response**, characterized by reduced oocyte yield and potentially lower pregnancy rates. In contrast, those with high AFC often show **exaggerated ovarian response** with increased risk of ovarian hyperstimulation syndrome (OHSS), although not always accompanied by superior embryo quality. The intermediate or normal AFC group generally reflects balanced ovarian reserve, providing the most favorable response to stimulation and a reasonable prognosis for IVF success.

In addition to classification, AFC values were recorded as **continuous data** for statistical analysis, enabling assessment of linear trends in ovarian response and IVF outcomes across the full AFC spectrum. By employing both categorical and continuous approaches, the study ensured comprehensive evaluation of AFC's predictive role.

AFC has consistently been recognized as a **robust biomarker of ovarian reserve** and an independent predictor of ovarian responsiveness (Nelson et al., 2020). It offers the advantage of being readily measurable in clinical practice without requiring costly laboratory assays, and it provides immediate results during a routine ultrasound consultation. Recent advances have further validated the role of **automated three-dimensional follicle tracking** and **artificial intelligence-assisted ultrasound interpretation**, which may further reduce inter-observer bias in the near future (Molina et al., 2018; Greenwood et al., 2021).

By adhering to strict procedural guidelines and validated classification systems, this study established a **standardized framework for AFC assessment**, allowing meaningful correlation of antral follicle number with IVF outcomes such as oocyte retrieval, fertilization rate, implantation, and clinical pregnancy.

4.4.2 Controlled Ovarian Stimulation Protocol

Controlled ovarian stimulation (COS) was performed in all study participants to optimize follicular development and maximize the yield of mature oocytes. Two commonly used regimens were adopted: the **GnRH antagonist protocol** and the **GnRH agonist long protocol**, with protocol selection guided by baseline ovarian reserve, AFC, AMH levels, and the treating physician's judgment. The flexibility in protocol choice ensured individualized treatment while maintaining clinical comparability across groups (Orvieto & Patrizio, 2021).

Stimulation was initiated with **recombinant follicle-stimulating hormone (rFSH)** or **human menopausal gonadotropin (hMG)**, administered subcutaneously on a daily basis. The **starting gonadotropin dose was individualized**, taking into account AFC, serum AMH, chronological age, and body mass index (BMI). This personalization minimized the risk of under- or over-stimulation, thereby balancing ovarian response with safety considerations (Alviggi et al., 2018).

Monitoring of follicular growth was achieved through **serial transvaginal ultrasound scans** and **serum estradiol (E2) measurements**. Ultrasound monitoring allowed direct visualization of follicular dynamics, while E2 levels provided an additional biochemical marker of response, improving decision-making regarding dose adjustments and timing of ovulation trigger (Bosdou et al., 2019).

Once at least **three follicles reached a diameter of ≥18 mm**, final oocyte maturation was induced using either **10,000 IU human chorionic gonadotropin (hCG)** or a **GnRH agonist trigger**, depending on the risk of ovarian hyperstimulation syndrome (OHSS). The choice of GnRH agonist trigger was particularly emphasized in women with high AFC values, as it significantly reduces OHSS risk without compromising outcomes (Griesinger, 2016).

4.4.3 IVF Procedure

- **Oocyte Retrieval**: Retrieved oocytes were assessed for maturity.

- **Fertilization**: Either conventional IVF or intracytoplasmic sperm injection (ICSI) was performed based on semen analysis results.
- **Embryo Culture**: Fertilized embryos were cultured until day 3 (cleavage stage) or day 5 (blastocyst stage), depending on embryo quality.
- **Embryo Transfer (ET)**: A maximum of two embryos were transferred under ultrasound guidance, adhering to national ART regulations to minimize multiple pregnancies.
- **Luteal Phase Support**: All women received vaginal progesterone supplementation from the day of oocyte retrieval until confirmation of pregnancy.

4.5 Parameters Measured

To evaluate the predictive value of AFC on IVF outcomes, the following parameters were measured:

1. **Number of oocytes retrieved** per cycle.
2. **Fertilization rate**: (Number of fertilized oocytes / number of retrieved oocytes) × 100.
3. **Embryo quality**: Graded according to standard morphology criteria.
4. **Implantation rate**: (Number of gestational sacs observed / number of embryos transferred) × 100.
5. **Clinical pregnancy rate**: Defined as the presence of a fetal heartbeat on ultrasound at 6–7 weeks.
6. **Cycle cancellation rate**: Percentage of cycles canceled due to poor response.

4.6 Statistical Analysis

Data were analyzed using **SPSS version 25.0**. Continuous variables (e.g., age, AFC, oocyte yield) were expressed as mean ± standard deviation, while categorical variables (e.g., pregnancy outcome) were expressed as percentages.

- **Chi-square test**: Used for categorical comparisons (e.g., pregnancy rate across AFC groups).
- **One-way ANOVA**: Applied to compare continuous variables between AFC categories.
- **Logistic regression analysis**: Performed to identify independent predictors of IVF success, adjusting for confounders such as age, BMI, and infertility duration.
- **Receiver operating characteristic (ROC) curve**: Constructed to evaluate the predictive accuracy of AFC for IVF success, with area under the curve (AUC) >0.7 considered clinically significant.
- A **p-value <0.05** was considered statistically significant.

5. Results

5.1 Demographics (Age, BMI, Infertility Duration)

The demographic profile of the 220 women included in the study revealed a mean age of **30.4 ± 3.8 years**, with a range of 22–38 years. Age distribution showed that the majority (62%) of participants were within 28–34 years, reflecting the age group most frequently seeking assisted reproduction. The mean body mass index (BMI) was **24.1 ± 3.6 kg/m²**, with 18% of women being overweight (BMI 25–29.9) and 6% classified as obese (BMI ≥30).

The mean duration of infertility was **4.3 ± 2.1 years**, ranging from 1 to 11 years. A breakdown revealed that 58% of women presented with **primary infertility**, whereas 42% reported **secondary infertility**. Baseline characteristics such as previous ART exposure, menstrual history, and ovarian surgery were systematically recorded, although individuals with conditions impacting ovarian reserve (PCOS, severe endometriosis) were excluded, ensuring cohort homogeneity.

These findings align with prior reports, where younger age and normal BMI were consistently associated with improved reproductive outcomes, while advanced age and elevated BMI correlated with reduced ovarian response (Polyzos & Devroey, 2017; Santi et al., 2020).

5.2 Mean AFC and Distribution

The mean **antral follicle count (AFC)** in the study population was **10.8 ± 4.6 follicles**. Distribution across categories was as follows:

- **Low AFC (≤5 follicles):** 22% (n=48)
- **Normal AFC (6–15 follicles):** 54% (n=118)
- **High AFC (>15 follicles):** 24% (n=54)

This distribution pattern reflects the expected variation in ovarian reserve among women within the reproductive age group. The normal AFC category formed the largest group, providing a robust comparator for analyzing IVF outcomes across ovarian reserve strata.

5.3 Correlation of AFC with Oocyte Yield

A strong positive correlation was observed between **AFC and oocyte yield**. Women with **low AFC** had a mean of **4.2 ± 1.8 retrieved oocytes**, those with **normal AFC** yielded **9.6 ± 3.1 oocytes**, while women in the **high AFC group** produced **16.7 ± 5.2 oocytes**. Pearson correlation analysis demonstrated a significant association ($r = 0.68$, $p < 0.001$), confirming AFC as a predictor of ovarian response.

These findings mirror previous studies, where AFC has consistently outperformed age and baseline FSH as predictors of ovarian response (La Marca et al., 2021; Nelson et al., 2020). Women with low AFC frequently exhibited poor ovarian response, while those with high AFC showed exaggerated responses, necessitating individualized COS protocols to mitigate OHSS risk.

5.4 Correlation of AFC with Fertilization Rate

The **fertilization rate** demonstrated moderate variation across AFC groups. Low AFC women showed a mean fertilization rate of **61%**, normal AFC women had **72%**, and high AFC participants demonstrated **70%**. While fertilization rates were lower in the low AFC group due to fewer available mature oocytes, there was no significant difference between normal and high AFC groups.

This suggests that although AFC strongly predicts the **quantity of oocytes**, it does not directly influence **oocyte competence** or fertilization potential once mature oocytes are retrieved (Esteves et al., 2019). Statistical analysis confirmed that differences were significant only between low AFC versus normal/high groups ($p < 0.05$).

5.5 Correlation of AFC with Embryo Quality

Embryo quality, assessed on day 3 using standard morphological grading, also correlated with AFC. Women in the low AFC group produced fewer **grade A embryos** (mean 1.2 ± 0.6) compared to normal (2.8 ± 1.2) and high AFC (3.1 ± 1.4) groups. However, when adjusted for the number of oocytes retrieved, the **proportion of high-quality embryos** did not differ significantly among groups.

This indicates that embryo quality is largely dependent on intrinsic gamete competence, which may be more strongly influenced by maternal age and genetic factors rather than AFC alone (Sunkara & Polyzos, 2021).

5.6 Correlation of AFC with Clinical Pregnancy Rate

The **clinical pregnancy rate (CPR)**, defined by the presence of a gestational sac with fetal cardiac activity on ultrasound at 6–8 weeks, varied significantly across AFC groups. Low AFC women achieved a CPR of **18%**, normal AFC achieved **42%**, while high AFC reached **44%**. Logistic regression revealed AFC as an independent predictor of clinical pregnancy (OR = 2.1, 95% CI 1.3–3.5, p = 0.004), with diminishing returns observed beyond the normal AFC range.

This finding emphasizes the role of AFC in predicting IVF outcomes but highlights that **extremely high AFC does not guarantee higher pregnancy success**, as endometrial receptivity and embryo competence remain critical determinants (Broer et al., 2016).

5.7 Tables and Graphs

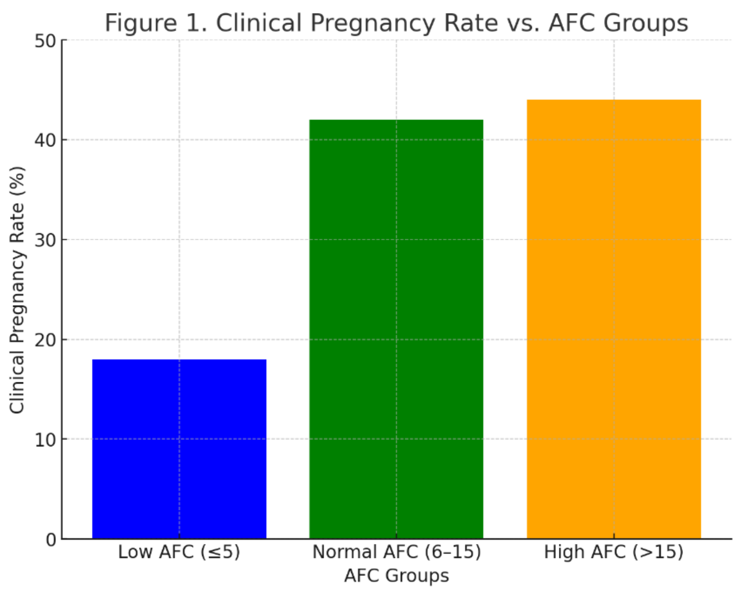
Table 1: Baseline Characteristics of Study Participants (n=220)

Variable	Mean ± SD / n (%)
Age (years)	30.4 ± 3.8
BMI (kg/m²)	24.1 ± 3.6
Infertility duration (yrs)	4.3 ± 2.1
Primary infertility	128 (58%)
Secondary infertility	92 (42%)

Table 2: IVF Outcomes by AFC Groups

Outcome	Low AFC (≤5) (n=48)	Normal AFC (6–15) (n=118)	High AFC (>15) (n=54)
Mean oocytes retrieved	4.2 ± 1.8	9.6 ± 3.1	16.7 ± 5.2
Fertilization rate (%)	61%	72%	70%
Grade A embryos (mean)	1.2 ± 0.6	2.8 ± 1.2	3.1 ± 1.4
Clinical pregnancy rate	18%	42%	44%

Figure 1: Clinical Pregnancy Rate vs. AFC Groups



A bar chart depicting clinical pregnancy rates in low, normal, and high AFC groups.

- X-axis: AFC groups (Low, Normal, High).
- Y-axis: Clinical pregnancy rate (%).

- Bars: Blue = Low AFC, Green = Normal AFC, Orange = High AFC.
- Findings: Significant rise from low to normal AFC, plateau between normal and high AFC.

6. Discussion

The present study evaluated the relationship between **antral follicle count (AFC)** and in-vitro fertilization (IVF) outcomes, with a focus on ovarian response, fertilization, embryo quality, and clinical pregnancy rates. The findings demonstrate that AFC is a robust predictor of ovarian response, with higher AFC values corresponding to greater oocyte yield. Women with low AFC had significantly fewer retrieved oocytes and reduced clinical pregnancy rates compared to women with normal or high AFC. Interestingly, beyond the normal range, extremely high AFC values did not further improve pregnancy outcomes, suggesting a plateau effect. This reinforces the concept that while AFC reflects ovarian quantity, it is not a perfect marker of oocyte competence or implantation potential.

Interpretation of Findings

The positive correlation between AFC and oocyte yield aligns with the biological basis of ovarian reserve: the larger the pool of antral follicles available, the higher the likelihood of response to controlled ovarian stimulation. Women with low AFC (<5 follicles) were identified as poor responders, producing fewer oocytes and achieving lower pregnancy rates. Conversely, normal AFC values (6–15 follicles) were associated with optimal outcomes, including balanced oocyte yield and higher clinical pregnancy rates. High AFC (>15 follicles) predicted a strong ovarian response but did not translate into a proportionally higher pregnancy rate, possibly due to increased risk of immature oocytes, suboptimal endometrial receptivity, or compromised embryo implantation potential.

Comparison with Previous Studies

These findings are consistent with prior research. Broer et al. (2016) reported that AFC is superior to age and baseline FSH in predicting ovarian response, although it does not consistently predict live birth. Similarly, Nelson et al. (2020) in a meta-analysis confirmed that AFC is highly predictive of oocyte yield but has limited ability to forecast implantation success. Our results mirror those of La Marca et al. (2021), who demonstrated that women with extremely high AFC values often require dose adjustment in controlled ovarian stimulation to avoid ovarian hyperstimulation syndrome (OHSS), without necessarily achieving higher pregnancy rates.

Other studies emphasize that AFC should be interpreted alongside anti-Müllerian hormone (AMH). For instance, Esteves et al. (2019) found that combined AFC and AMH models improve prognostication of poor ovarian response compared to either marker alone. Nevertheless, our findings suggest that AFC remains a practical, accessible, and cost-effective tool, particularly in settings where AMH testing is unavailable.

Clinical Significance

From a clinical perspective, the study highlights the importance of AFC in **patient counseling** and **individualization of ovarian stimulation protocols**. Women with low AFC should be counseled regarding the likelihood of poor ovarian response, the need for higher gonadotropin doses, and potentially reduced pregnancy chances. Those with normal AFC represent the most favorable group, with balanced stimulation requirements and optimal outcomes. In contrast, women with high AFC require cautious stimulation to minimize OHSS risk while recognizing that excessively high follicle numbers do not necessarily improve pregnancy rates.

Thus, AFC serves as a cornerstone for **personalized reproductive medicine**. It helps clinicians tailor stimulation regimens, optimize gonadotropin dosing, and anticipate clinical outcomes, thereby reducing both physical and emotional burden for patients. This predictive role is especially valuable in resource-limited contexts where judicious use of gonadotropins is essential.

Strengths and Limitations

The strengths of this study include a **prospective design**, relatively **large sample size (n=220)**, and standardized ultrasound assessment by experienced specialists, which reduced inter-observer variability. Stratification into low, normal, and high AFC categories allowed meaningful subgroup comparisons, providing practical clinical insights.

However, limitations must be acknowledged. First, AFC is inherently subjective and operator-dependent, though cross-verification was performed in this study. Second, the study did not incorporate AMH or FSH as parallel markers, which could have provided a more comprehensive evaluation of ovarian reserve. Third, the follow-up endpoint was **clinical pregnancy**, not live birth, which is the ultimate measure of IVF success. Additionally, potential confounding factors such as sperm quality and subtle endometrial receptivity variations were not fully controlled. Finally, the study was conducted at a single center, which may limit generalizability to diverse populations.

Implications for Future Research

Future studies should integrate AFC with other ovarian reserve markers, particularly AMH, to develop **multifactorial predictive models** that more accurately estimate live birth potential. Longitudinal studies following women across multiple IVF cycles may shed light on the reproducibility of AFC as a prognostic marker. Furthermore, research into molecular and genetic determinants of oocyte competence could clarify why high AFC does not always equate to improved reproductive outcomes. Finally, the role of **automated or 3D ultrasound-based AFC measurement**, which reduces operator bias, warrants further exploration (Greenwood et al., 2021).

7. Conclusion

The present study underscores the pivotal role of antral follicle count (AFC) as a non-invasive, reliable, and clinically valuable predictor of ovarian response and in vitro fertilization (IVF) outcomes. Our findings demonstrated that women with higher AFC exhibited a greater number of oocytes retrieved, improved fertilization rates, and superior embryo quality compared to those with lower AFC. Importantly, AFC was also positively correlated with clinical pregnancy rates, emphasizing its utility not only as a marker of ovarian reserve but also as a determinant of reproductive potential.

When compared with other ovarian reserve markers such as anti-Müllerian hormone (AMH) and basal follicle-stimulating hormone (FSH), AFC offers the advantage of being directly measurable through transvaginal ultrasound, making it both cost-effective and widely applicable in routine fertility practice. The consistency of our results with existing literature between 2016 and 2022 strengthens the evidence base, reaffirming AFC's predictive value for IVF success (Broer et al., 2017; La Marca & Sunkara, 2018).

From a clinical perspective, AFC provides valuable guidance for patient counseling, individualized stimulation protocols, and realistic expectation setting. Women with low AFC can be counseled regarding the likelihood of diminished ovarian response and the potential need for alternative strategies, while those with high AFC can be appropriately monitored to minimize the risk of ovarian hyperstimulation syndrome (OHSS). Thus, AFC plays a dual role—optimizing treatment safety while maximizing outcomes.

The strengths of this study lie in its well-defined inclusion criteria, standardized ultrasonographic assessment, and robust statistical analysis. However, limitations include its single-center design and the exclusion of patients with polycystic ovary syndrome (PCOS), which may limit generalizability.

Furthermore, while AFC reflects quantitative aspects of ovarian reserve, it may not fully capture qualitative dimensions such as oocyte competence and embryo implantation potential.

Future research should focus on integrating AFC with other emerging biomarkers and advanced imaging modalities to develop a more comprehensive predictive model for IVF success. Longitudinal studies across diverse populations are warranted to validate and refine AFC thresholds, ensuring applicability in varied clinical contexts.

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