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Discrepancies between anti-Müllerian hormone and age: Their combined impact on intracytoplasmic sperm injection results

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ABSTRACT

Objective: To investigate the impact of anti-Müllerian hormone (AMH) levels on the outcomes of intracytoplasmic sperm injection (ICSI) cycles in women of advanced age and also to explore the effect of age on the ICSI results in patients with low AMH levels.

Methods: This retrospective cohort study involved 143 infertile couples undergoing ICSI cycles at a fertility clinic in Iran from November 2021 to November 2023. Women aged <37 years with AMH <1 ng/mL and those aged ≥37 years were included. A standardized ovarian stimulation protocol was followed, leading to oocyte retrieval and ICSI on mature oocytes. Key oocyte quality indexes, including the maturation rate, fertilization rate, and embryo quality metrics, were evaluated. Poisson regression analyses were also employed to investigate the association between AMH levels and oocyte quality parameters in the advanced age groups, as well as the association between age and oocyte quality parameters in patients with low AMH.

Results: We analyzed 143 ICSI cycles from 143 infertile couples. The mean ages of the women and their partners were (38.2±4.7) years and (40.6±5.9) years, respectively, with a median (IQR) AMH level of 0.7 (0.4–2.0) ng/mL. Younger women with low AMH levels (<1 ng/mL) showed significantly better outcomes in terms of the number of MII oocytes [adjusted odds ratio (aOR) 1.89, 95% CI 1.31–2.71; *P*=0.001], fertilized (2PN) oocytes (aOR 1.97, 95% CI 1.36–2.86; *P*<0.001), embryo number (aOR 2.16, 95% CI 1.44–3.24; *P*<0.001), and embryos suitable for freezing (aOR 2.88, 95% CI 1.80–4.61; *P*<0.001) compared to advanced-age women. Furthermore, among women of advanced age, those with normal AMH levels exhibited a significantly higher number of MII oocyte (aOR 3.55, 95% CI 2.31–5.44; *P*<0.001), fertilized (2PN) oocytes (aOR 3.54, 95% CI 2.29–5.49; *P*<0.001), embryo number (aOR 3.89, 95% CI 2.48–6.10; *P*<0.001), and embryos suitable for freezing (aOR 4.75, 95% CI 2.79–8.09; *P*<0.001) compared to those with low AMH levels.

Conclusions: AMH level is a significant predictor of oocyte and embryo number and quality in infertile women of advanced age undergoing ICSI cycles. Our findings suggest that maternal age markedly impacts the quality of oocytes and embryos in low AMH-level patients.

Key Points

Question: How do age and anti-Müllerian hormone (AMH) levels influence oocyte/embryo quality and intracytoplasmic sperm injection (ICSI) outcomes in infertile women?

Findings: In this retrospective cohort study of 143 ICSI cycles, women aged <37 years with low AMH had significantly better oocyte maturation, fertilization, and viable embryo rates than those aged ≥37 years. Additionally, in advanced-age women (≥37 years), normal AMH levels (>1 ng/mL) independently predicted superior oocyte/embryo quantity and quality *versus* low AMH.

Meaning: Both AMH and age are critical predictors of ICSI success, with younger women maintaining better outcomes despite low AMH, while older women require normal AMH for optimal results.

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KEYWORDS: Intracytoplasmic sperm injection; Assisted reproductive technology; Age; Anti-Müllerian hormone; Oocyte quality; Retrieved oocyte number

1. Introduction

Infertility rates are increasingly prevalent in modern societies, with approximately 50 million couples worldwide classified as infertile, and around 12.5% of women in the world suffer from infertility[1–3]. A variety of approaches, including assisted reproductive technology (ART), have been implemented to address this issue. However, the success rate in ART remains approximately 35% regarding pregnancy per embryo transferred[4,5]. While ongoing pregnancies and live births are critical outcomes, these are significantly influenced by the number and quality of oocytes and embryos. Oocyte quality is a critical factor influencing female fertility, as it is essential for successful fertilization and subsequent embryo development[6].

Reports indicate that even with techniques like intracytoplasmic sperm injection (ICSI), fertilization of human oocytes can still be unsuccessful, with an estimated occurrence rate of 3%[7]. This indicates the complexity of successful fertilization, which depends not only on sperm penetration but also on several intrinsic factors related to oocyte quality. Consequently, successful pregnancies or live births in ARTs rely on both the quantity and quality of retrieved oocytes, highlighting the need for reliable markers to assess ovarian reserve and predict outcomes.

The anti-Müllerian hormone (AMH) is a specific peptide produced by developing ovarian follicles, playing a key role in regulating folliculogenesis in women[8]. AMH serves as an important biomarker for predicting ovarian response to controlled stimulation and cycle cancellation[9]. AMH has emerged as a biomarker and predictor of clinical pregnancy outcomes of ART[10–12]. Numerous studies have explored the significance of AMH levels in predicting pregnancy outcomes[13–16]. However, some clinical research has indicated that during an *in vitro* fertilization (IVF) cycle, AMH levels do not effectively predict oocyte quality in women under 35 years, but other studies showed inconsistent results[17,18]. Additionally, some research suggests different age thresholds for the prognostic impact of AMH on ART outcomes. Although some other studies believe that the predictive effect of AMH on the outcome of ART is prominent regardless of age[11,19].

To address this, we conducted a retrospective analysis of the correlation between baseline AMH levels and ICSI outcomes in women of advanced age and also investigated the impacts of age on the ICSI results in patients with low AMH levels.

2. Methods

2.1. Patients' selection and study design

This retrospective cohort study was conducted on 143 infertile

couples who underwent ICSI cycles at the Shahid Beheshti fertility clinic, affiliated with Isfahan University of Medical Sciences (Isfahan, Iran), between November 2021 and November 2023.

Women under 37 years of age with an AMH level of less than 1 ng/mL and all women over 37 years of age who underwent an ICSI cycle with gonadotropin-releasing hormone (GnRH) agonist protocol were enrolled. Furthermore, only couples with normozoospermic male partners and no identified male factor infertility were included. Women with a previous history of ovarian surgery, polycystic ovary syndrome, pelvic radiotherapy, or chemotherapy, as well as those with hormonal therapy in the six months before entering the study, were excluded.

At first, the participants with age ≥ 37 years were divided into two groups based on AMH levels: the normal AMH group (AMH ≥ 1 ng/mL, $n=49$) and the low AMH group (AMH < 1 ng/mL, $n=57$). Then, women with AMH levels < 1 ng/mL were divided according to their age into two sets: age < 37 years ($n=37$) and age ≥ 37 years ($n=57$). Figure 1 is a flowchart of the study.

Sample size was calculated using G-Power software, with $\alpha=0.05$, statistical power of 80%, and a minimum standardized effect size of 0.35. Based on these parameters, a minimum of 60 participants per group was required for both the AMH < 1 ng/mL and AMH ≥ 1 ng/mL cohorts, resulting in a total sample size of 120. Potential selection bias was mitigated by applying strict inclusion/exclusion criteria retrospectively. Measurement bias was minimized through standardized laboratory protocols (*e.g.*, single lab for AMH assays, uniform embryo/oocyte grading).

2.2. AMH assay

AMH measurement was performed in a single accredited laboratory situated within the study setting. Baseline serum AMH concentration was determined by an enzyme-linked immunosorbent assay, in accordance with the manufacturer's instruction (ELISA, AMH ELISA kit; Kangrun Biotech, China) on days 2–3 of the spontaneous menstrual cycle before ICSI treatment.

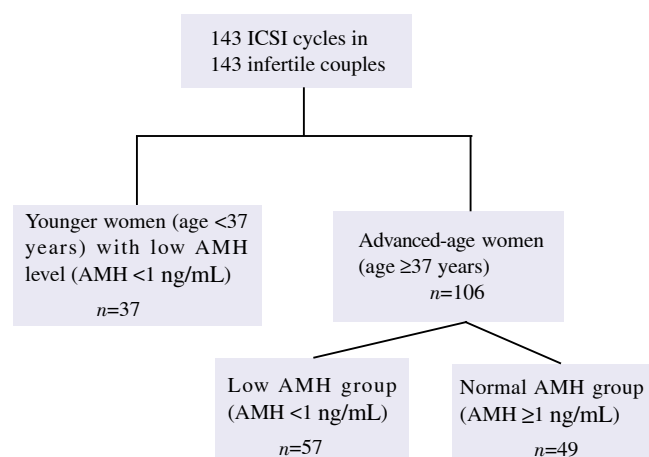


Figure 1. Flowchart of the study.

2.3. Ovarian stimulation protocol

All participants underwent a standardized ovulation induction protocol, which commenced on the second day of their menstrual cycle. They received daily subcutaneous injections of recombinant human follicle-stimulating hormone (r-hFSH; Gonal-F) at a dosage of 150-250 IU based on AMH level for six consecutive days. From the fourth day of the cycle, participants also received intramuscular injections of human menopausal gonadotropin (hMG; Menogon, Ferring Pharmaceuticals A/S, Copenhagen, Denmark) at a daily dose of 75 IU, continuing until the trigger day. Then, transvaginal sonography was performed from day 7 of the menstrual cycle, and then it was repeated every other day.

When at least three mature follicles (≥ 14 mm) were detected, subcutaneous administration of Cetrotide (Merck Serono, Germany) at 250 μ g per day was initiated and continued until the trigger day. If more than three mature follicles (≥ 17 mm in diameter) were observed *via* transvaginal ultrasound, a subcutaneous injection of 0.2 mg GnRH analog triptorelin (Decapeptyl, Paris, France) was given. Oocyte retrieval was scheduled 35-36 hours post-administration of the trigger, using a 17 G ovum aspiration needle (Prince, Paris, France) through transvaginal ultrasound guidance.

2.4. ICSI procedure

On the day of oocyte pickup, the semen sample was obtained by masturbation after 2-4 days of sexual abstinence into sterile, non-toxic plastic vials, which have been incubated for 30 minutes to facilitate liquefaction. The retrieved oocytes were kept in a culture medium for 2 to 3 hours, then cumulus cells surrounding the retrieved oocytes were mechanically removed using 80 IU/mL hyaluronidase (Origio, Denmark) preheated to 37°C. Then, oocytes were assessed for maturity. Metaphase 2 (MII) oocytes were confirmed with an inverted microscope before performing ICSI. The injected MII oocytes were transferred into SAGE 1-Step medium (Origio, Denmark), covered with mineral oil, and cultured in an incubator at 37°C with 6% CO₂ and 5% O₂.

2.5. Fertilization and embryo assessment

The day after ICSI injection, fertilization status was assessed by observing pronuclei in the cytoplasm, where the presence of two pronuclei indicated normal fertilization. By the third day, cleavage embryos were graded based on criteria including morphology, fragmentation amount, blastomere count, and symmetry.

The data, including the retrieved oocytes, the assessment of oocyte quality, the total number of embryos, and embryo quality, were collected based on the first cycle in each patient.

Oocyte quality was evaluated morphologically by examining the maturation stage of the oocyte nucleus, categorizing them as MII for

mature oocytes and metaphase I (MI) and germinal vesicle (GV) for immature oocytes.

2.6. Main outcome measures

Demographic characteristics included AMH levels, the couple's age, and the duration of infertility. The primary outcomes measured included retrieved oocyte number and the number of MII oocytes, MI oocytes, GV cells, fertilized oocytes [two-pronuclear zygote (2PN)], embryos, and embryos suitable for freezing.

Secondary outcomes measured were the oocyte maturation rate, fertilization rate, embryo formation rate, and the rate of embryos suitable for freezing. The oocyte maturation rate was defined as the percentage of mature oocytes (MI oocytes) in all retrieved oocytes. Fertilization rate was defined as the percentage of fertilized oocytes (2PN) to all mature oocytes (MI). The embryo formation rate was calculated as the percentage of embryo formation to fertilized oocytes (2PN). The rate of embryos suitable for freezing was calculated as the percentage of embryos suitable for freezing to fertilized oocytes (2PN).

2.7. Statistical analysis

Data analysis was carried out on IBM SPSS Statistics 26.0 (IBM Corp., Armonk, New York, USA). The normality of all continuous variables was checked using the Kolmogorov-Smirnov test and the Shapiro-Wilk test as appropriate. For descriptive statistics, we used the χ^2 test for categorical variables and the independent samples *t*-test or Mann-Whitney *U* test for continuous variables. Categorical data were represented using frequencies and percentages, and continuous data were expressed as the mean $\pm$ standard deviation (mean $\pm$ SD) or median [interquartile range (IQR)].

We performed Poisson regression analyses to investigate the relationship between AMH levels and oocyte quality parameters in the advanced age groups as well as the relationship between age and oocyte quality parameters in the low AMH patients, and we estimated odds ratio (OR) with 95% confidence interval (CI). To account for the confounding factor, a multivariate Poisson regression model was utilized. A significance level of 5% ($P < 0.05$) was adopted to determine statistical significance.

2.8. Ethics statement

This study obtained ethical clearance from the Ethics Committee of the Isfahan University of Medical Science (ethical number: IR.MUI.MED.REC.1403.023, approved on: 2024-10-01), adhering to the ethical guidelines outlined in the Declaration of Helsinki. Due to the retrospective nature of this study, informed consent was waived. Patient information was coded and anonymized to ensure that it remained confidential.

3. Results

3.1. Baseline characteristics of the study participants

In this study, a total of 143 ICSI cycles were evaluated in 143 infertile couples. The mean age of the women included in the study was (38.2±4.7) years old, and the mean age of their husbands was (40.6±5.9) years old. Additionally, the median (IQR) duration of infertility of the couples was 4 (3-7) years (Table 1). The median (IQR) of the basal AMH level was 0.7 (0.4–2.0) ng/mL in the study participants.

3.2. Comparison of ICSI outcomes in low AMH patients in different age-categorized groups

The comparison of ICSI parameters in patients with low AMH levels indicated that the number of MII oocytes, the number of fertilized oocytes, the number of embryos, and the number of embryos suitable for freezing were significantly higher in the younger group compared to the older age group ($P<0.001$). Furthermore, the number of MI oocytes ($P=0.006$) and GV cells ($P=0.005$) were significantly lower in the younger women compared to the women of advanced age. Additionally, the oocyte maturation rate, fertilization rate, and embryo suitability for freeze rate were significantly higher in younger patients. However, there was no significant difference in the number of retrieved oocytes and the embryo formation rate between the two groups (Table 2).

3.3. Predictive value of age on ICSI outcomes in low AMH patients

The Poisson regression analyses confirm that in the low AMH

group of patients, women under 37 years old had substantially higher chances of retrieving MII oocytes, fertilized (2PN) oocytes, embryo number, and embryos suitable for freezing compared to those ≥ 37 years ($P<0.001$). These results remained significant after adjustment for AMH level. Younger women with low AMH levels showed significantly better outcomes in terms of the number of MII oocytes [adjusted odds ratio (aOR) 1.89, 95% CI 1.31-2.71; $P=0.001$], fertilized (2PN) oocytes (aOR 1.97, 95% CI 1.36-2.86; $P<0.001$), embryo number (aOR 2.16, 95% CI 1.44-3.24; $P<0.001$), and embryos suitable for freezing (aOR 2.88, 95% CI 1.80-4.61; $P<0.001$) compared to older patients (Table 3).

3.4. Comparison of ICSI outcomes based on AMH levels in advanced age

Table 4 shows the oocyte and embryo quality and quantity parameters in the low AMH and normal AMH groups in the advanced-age cohort of patients. Analyses revealed that the population of women older than 37 years with AMH levels ≥ 1 ng/mL had a significantly higher number of retrieved oocytes, mature (MII) oocytes, fertilized (2PN) oocytes, embryo number, and higher number of embryo suitable for freezing compared to the population with AMH levels <1 ng/mL ($P<0.001$). Surprisingly, the number of MI oocytes ($P=0.09$) and GV cells ($P=0.06$) were higher but not significant in the patients with AMH levels ≥ 1 ng/mL compared to those with AMH levels <1 ng/mL.

Moreover, in the older group of patients, a trend toward a higher oocyte maturation rate was observed in the normal AMH group (83.33%) with respect to the low AMH group (58.33%) ($P=0.04$), whereas no statistically significant differences between the two groups were observed in terms of fertilization rate, embryo formation rate, or embryo suitable for freezing rate.

Table 1. Baseline characteristics of study participants.

Variables	Total (n=143)	Younger women (age <37 years) (n=37)	Advanced-age women (age ≥ 37 years) (n=106)	
			Low AMH group (AMH <1 ng/mL)	Normal AMH group (AMH ≥ 1 ng/mL)
Age, years	38.2±4.7	32.1±3.9	41.6±2.4	38.7±1.9
Partner's age, years	40.6±5.9	36.1±5.7	43.5±3.9	40.1±2.9
Infertility duration, years	4 (3-7)	3 (2-4)	5 (3-8)	3 (2-4)

Data are presented as mean±SD or median (IQR). AMH: anti-Müllerian hormone.

Table 2. Comparison of oocyte and embryo number and quality in low AMH patients in different age categorized groups.

Parameters	AMH <1 ng/mL (n=94)		P-value
	Age <37 years (n=37)	Age ≥ 37 years (n=57)	
Retrieved oocyte number	2 (1-3)	2 (1-3)	0.22
MII oocyte number	2 (1-2)	1 (0-2)	<0.001
MI oocyte number	0 (0-0)	0 (0-0)	0.006
GV cell number	0 (0-0)	0 (0-1)	0.005
Fertilized oocyte (2PN) number	2 (1-2)	1 (0-1.5)	<0.001
Number of embryo	1 (1-2)	1 (0-1)	<0.001
Number of embryos suitable for freeze	1 (1-2)	1 (0-1)	<0.001
Oocyte maturation rate, %	90.38±22.87	50 (0-100)	<0.001
Fertilization rate, %	100 (89.28-100)	50 (0-100)	<0.001
Embryo formation rate, %	89.51±29.41	82.51±32.01	0.39
Rate of embryos suitable for freeze, %	100 (70.83-100)	58.33 (0-100)	0.007

Comparison is done by Mann Whitney-U test or independent samples t-test. Data are presented as median (IQR) or mean±SD. MII: metaphase II, MI: metaphase I, GV: germinal vesicle, 2PN: two-pronuclear zygote, AMH: anti-Müllerian hormone.

Table 3. Regression analysis of age <37 years vs. age ≥37 years on oocyte and embryo number and quality in low AMH patients.

Parameters	Crude model			Adjusted model		
	OR	95% CI	P-value	OR	95% CI	P-value
Retrieved oocyte number	1.24	0.93-1.64	0.13	1.15	0.85-1.56	0.33
MII oocyte number	2.01	1.43-2.82	<0.001	1.89	1.31-2.71	0.001
Fertilized oocyte (2PN) number	1.96	1.37-2.79	<0.001	1.97	1.36-2.86	<0.001
Number of embryo	2.27	1.55-3.33	<0.001	2.16	1.44-3.24	<0.001
Number of embryo suitable for freeze	3.18	2.04-4.96	<0.001	2.88	1.80-4.61	<0.001

AMH: anti-Müllerian hormone, MII: metaphase II, 2PN: two-pronuclear zygote, OR: odds ratio, CI: confidence interval. Reference group: women aged ≥37 years.

Table 4. Comparison of oocyte and embryo number and quality based on AMH levels in advanced age patients.

Parameters	Age ≥37 years (n=106)		P-value
	AMH <1 ng/mL (n=57)	AMH ≥1 ng/mL (n=49)	
Retrieved oocyte number	2 (1-3)	6 (4-9)	<0.001
MII oocyte number	1 (0-2)	4 (3-7)	<0.001
MI oocyte number	0 (0-0)	0 (0-0.5)	0.09
GV Cell number	0.5 (0-1)	1 (0-1.5)	0.06
Fertilized oocyte (2PN) number	1 (0-1)	4 (2-6)	<0.001
Number of embryo	1 (0-1)	4 (2-5)	<0.001
Number of embryos suitable for freeze	0 (0-1)	3 (2-4)	<0.001
Oocyte maturation rate, %	58.33 (0-100)	83.33 (70-100)	0.04
Fertilization rate, %	85.27±28.67	90.64±18.26	0.37
Embryo formation rate, %	82.51±32.01	89.28±19.27	0.29
Rate of embryos suitable for freeze, %	66.66 (0-100)	80 (50-100)	0.08

Comparison is done by Mann Whitney-U test or independent samples t-test. Data are presented as median (IQR) or mean±SD. MII: metaphase II, MI: metaphase I, GV: germinal vesicle, 2PN: two-pronuclear zygote, AMH: anti-Müllerian hormone.

Table 5. Regression analysis of normal vs. low AMH levels on oocyte and embryo number and quality in older cohort of patients.

Parameters	Crude model			Adjusted model		
	OR	CI	P-value	OR	CI	P-value
Retrieved oocyte number	3.27	2.50-4.29	<0.001	2.75	2.01-3.76	0.01
MII oocyte number	4.69	3.20-6.87	<0.001	3.55	2.31-5.44	<0.001
Fertilized oocyte (2PN) number	4.54	3.08-6.69	<0.001	3.54	2.29-5.49	<0.001
Number of embryo	4.99	3.38-7.38	<0.001	3.89	2.48-6.10	<0.001
Number of embryo suitable for freeze	6.53	4.53-10.54	<0.001	4.75	2.79-8.09	<0.001

AMH: anti-Müllerian hormone, MII: metaphase II, 2PN: two-pronuclear zygote, OR: odds ratio, CI: confidence interval. Reference group: low AMH level.

3.5. Predictive value of AMH levels on ICSI outcomes in advanced age

The Poisson regression analyses further confirmed that among the older cohort of patients, normal AMH level was a significant predictor of oocyte and embryo quantity as well as quality parameters, including retrieved oocyte number, MII oocyte number, fertilized (2PN) oocytes, embryo number, and embryos suitable for freezing compared to the low AMH group ($P<0.001$). These results remained significant after adjustment for female age. Among women of advanced age, those with normal AMH levels exhibited a significantly higher number of MII oocyte (aOR 3.55, 95% CI 2.31-5.44; $P<0.001$), fertilized (2PN) oocytes (aOR 3.54, 95% CI 2.29-5.49; $P<0.001$), embryo number (aOR 3.89, 95% CI 2.48-6.10; $P<0.001$), and embryos suitable for freezing (aOR 4.75, 95% CI 2.79-8.09; $P<0.001$) compared to those with low AMH levels (Table 5).

4. Discussion

In this retrospective cohort study, we demonstrate that in infertile

women of advanced age (37 years and older) who underwent ICSI cycles, AMH level emerged as an independent predictive factor of the number and quality of oocytes and embryos. Furthermore, within two age-categorized groups with low AMH levels, our results suggest that while the number of retrieved oocytes is not affected by age in these patients, oocyte maturation rate, fertilization rate, the rate of embryos suitable for freezing, and the number and quality of embryos were influenced by age.

Age should be considered in the therapeutic planning of women with low AMH levels in terms of pregnancy rates. However, in young patients, low AMH levels can reflect a pathological condition and not a physiological reduction of ovarian reserve as in older women[7]. Research demonstrated that a low serum AMH level might suggest early ovarian aging and a quicker loss of oocytes; however, it may not completely represent "early ovarian aging" due to the favorable pregnancy outcomes that have been seen[6].

Our results corroborate these findings, showing that younger women with low AMH levels had substantially higher chances of retrieving mature oocytes, achieving fertilization, and producing embryos compared to their older counterparts. In these low AMH level patients, even after adjusting for AMH levels, the number of

mature and fertilized oocytes, as well as the number of embryos and the number of embryos suitable for freezing, is 1.89, 1.97, 2.16, and 2.88 times higher, respectively, than that of older women. This aligns with the results of a previous cohort study that examined 858 IVF/ICSI cycles in females with poor ovarian response (POR), where they reported that females with POR under 35 years old showed significantly higher numbers of mature oocytes, better embryo scores, and higher clinical pregnancy rates compared to those aged 35–40 and over 40 years. They suggested that maternal age is the primary determinant of successful IVF outcomes in low-oocyte producers[20].

In younger women with low AMH levels, even when the number of retrieved oocytes is limited due to low ovarian reserve, this quantity can still exhibit an appropriate success rate in developing into high-potential embryos. Furthermore, a single embryo capable of leading to a live birth is sufficient for the patient to achieve pregnancy[21,22].

Inconsistent with our results, a retrospective study examining 210 infertile women with AMH levels less than 1.1 ng/mL reported that age can affect the number of retrieved oocytes under the same conditions of AMH and other variables. They also reported that in individuals over 35 years old, the likelihood of retrieving more than three oocytes was 97.1% lower than in those younger than 35 years old[23].

Another significant finding from our study is that, in the analysis of women over 37 years of age, those with normal AMH levels demonstrated markedly better ICSI outcomes compared to those with low AMH levels. Furthermore, AMH levels serve as a predictive factor for both embryo and oocyte quality and quantity.

Our results are supported by those obtained in previous literature[24,25]. Kato *et al* demonstrated that the AMH level is a predictor of live birth among women older than 38 years[26]. Moreover, they failed to show such results in younger patients. They observed statistically significant differences in retrieved oocyte number between younger patients with low and normal AMH levels. However, there were not any differences in terms of pregnancy and live birth rate between the two aforementioned groups. The lack of significant differences in the pregnancy and live birth rate along with a significantly lower number of retrieved oocytes in younger patients with low AMH levels compared to those with normal AMH levels suggests that in younger patients, while the number of retrieved oocytes may be affected by AMH levels, the quality of those oocytes certainly is not.

Since in this study, both the number of MII oocytes and the number of fertilized oocytes were higher in the advanced age group with normal AMH levels compared to the same age group with low AMH levels, the fertilization rate was not different in these two groups. Such a result cannot be interpreted as no effect of AMH levels on ICSI outcome at older ages, like what Dai *et al* reported[27]. They showed that AMH levels were strongly correlated with the number of retrieved oocytes in older women. They also found that low AMH levels in women of advanced age did not affect the fertilization rate, but the rate of MII oocytes increased and the rate of top embryo formation decreased. They suggest that top embryo accumulation through multiple oocyte retrieval procedures is a good strategy for

treating women of advanced age.

Our results advocate for the incorporation of both age and AMH level assessments into pre-treatment counseling. For women over 37 years old, those with normal AMH levels could be prioritized for ICSI cycles due to their enhanced likelihood of successful outcomes. Conversely, advanced-age women with low AMH levels may require additional support to optimize their chances of conception.

This study has several limitations that should be noted. The retrospective design may introduce biases inherent to patient selection and data collection. Additionally, the analysis of embryo quality did not consider sperm and other male factors that could influence embryo quality. It is important to note that our study primarily aimed to evaluate oocyte quality rather than embryo quality.

In conclusion, this study highlights the critical role of AMH levels as an independent predictor of oocyte and embryo quality in infertile women undergoing ICSI, particularly those of advanced age. Our findings indicate that younger patients with low AMH levels and a reduced ovarian reserve may still have a favorable ICSI outcome due to a well-preserved oocyte quality. These insights emphasize the importance of considering both AMH levels and maternal age in the management and counseling of patients seeking ARTs.

Conflict of interest statement

The authors have no competing interests.

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Authors' contributions

Marzieh Derakhshan, Maryam Derakhshan, Elham Naghshineh, Minoo Movahedi, and Hatav Ghasemi-Tehrani contributed to the conception and design of the study. Atefeh Bamarinejad and Fatemeh Bamarinejad conducted the data analysis and were primarily responsible for drafting the manuscript. These authors also played key roles in critically reviewing, and substantially editing the manuscript to ensure the validity and accuracy of the results. Zahra Jafarzadeh, Marzieh Derakhshan, and Maryam Derakhshan carried out the ethical procedure as well as they contributed to the data collection. All contributing authors approved the final manuscript.

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