Research Article

Maternal And Neonatal Outcomes In Singleton Pregnancies Following In Vitro Fertilisation: A Retrospective Cohort Study With Adjusted Risk Estimates

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Abstract

Background
Singleton pregnancies conceived through in vitro fertilisation (IVF) have been associated with adverse maternal and neonatal outcomes; however, the extent to which these risks persist after adjustment for maternal characteristics remains uncertain, particularly in low- and middle-income settings.
Objective:
To compare maternal and neonatal outcomes between IVF-conceived and spontaneously conceived singleton pregnancies in a tertiary care setting.
Methods:
This retrospective cohort study included 70 IVF-conceived and 140 spontaneously conceived singleton pregnancies delivered between January and December 2025. Frequency matching was performed for maternal age and parity. Multivariable logistic regression was used to estimate adjusted odds ratios (aORs) with 95% confidence intervals, controlling for maternal age, body mass index, and parity.
Results:
IVF conception was associated with higher odds of cesarean delivery (aOR 11.06, 95% CI 5.26–23.22), hypertensive disorders of pregnancy (aOR 3.42, 95% CI 1.33–8.80), and gestational diabetes mellitus (aOR 4.86, 95% CI 2.28–10.37). Neonatal outcomes, including preterm birth (aOR 5.62, 95% CI 2.60–12.13) and low birth weight (aOR 2.40, 95% CI 1.16–4.99), were also more frequent in IVF pregnancies. Estimates for less common outcomes were imprecise. Subgroup analyses within the IVF cohort did not show consistent associations between treatment-related factors and adverse outcomes.
Conclusions:
In this cohort, IVF conception was associated with higher observed rates of several maternal and neonatal outcomes after adjustment for selected maternal characteristics. These findings should be interpreted cautiously, given the potential for residual confounding and centre-specific clinical practices. Larger prospective studies are needed to clarify the independent contribution of IVF-related factors.

Keywords: In vitro fertilization; singleton pregnancy; maternal outcomes; neonatal outcomes; preterm birth; low birth weight.

Introduction:

Assisted reproductive technologies (ART), particularly in vitro fertilization (IVF), have revolutionized the management of infertility and contributed significantly to global reproductive outcomes. Since the birth of the first IVF-conceived infant, the use of ART has increased substantially worldwide, driven by delayed childbearing, lifestyle factors, and expanding clinical indications.(1,2) Despite these advances, concerns remain regarding the safety of IVF pregnancies, particularly in relation to adverse maternal and neonatal outcomes.

Initially, the increased risk associated with IVF was largely attributed to multiple gestations; however, emerging evidence suggests that even singleton pregnancies conceived through IVF have been reported to be associated with higher rates of adverse outcomes compared with spontaneous conceptions.(3,4) Maternal risks reported in IVF pregnancies include hypertensive disorders of pregnancy, gestational diabetes mellitus, and higher rates of operative delivery, particularly caesarean section.(5–7) Several mechanisms have been proposed, although these remain incompletely understood. They likely reflect a combination of factors, including altered placentation, hormonal influences, and underlying infertility-related pathology.

Neonatal outcomes following IVF have also been a subject of extensive investigation. Studies have consistently demonstrated increased risks of preterm birth, low birth weight, very low birth weight, and neonatal intensive care unit (NICU) admission among IVF-conceived singletons.(3,8,9) Although the precise mechanisms remain

unclear, proposed explanations include epigenetic modifications, laboratory manipulation of gametes and embryos, and differences in endometrial receptivity associated with assisted reproduction techniques.(10) Interpretation of these associations is challenging due to the presence of confounding variables such as advanced maternal age, nulliparity, and underlying infertility, all of which independently contribute to adverse outcomes.(4,11) Furthermore, heterogeneity in IVF practices—including fertilization techniques such as intracytoplasmic sperm injection (ICSI), fresh versus frozen embryo transfer, and the use of donor gametes—may differentially influence both maternal and neonatal outcomes.(12,13) While several studies have attempted to adjust for these factors, residual confounding remains a limitation, and findings are not always consistent across populations.

In the Indian context, there is a relative paucity of robust, adjusted analyses examining IVF outcomes, with many studies limited by small sample sizes or lack of appropriate control groups. Given the increasing utilization of ART in tertiary care settings, there is a need for context-specific evidence to guide clinical practice and patient counselling. Additionally, few studies have explored the contribution of IVF-specific clinical characteristics to adverse outcomes within the IVF population itself. Given these uncertainties, distinguishing the contribution of IVF procedures from underlying infertility and maternal characteristics remains a key challenge in observational research.

Therefore, this retrospective cohort study was conducted to compare maternal and neonatal outcomes in singleton pregnancies conceived via IVF and spontaneous conception in a tertiary care setting. By employing frequency matching and multivariable regression modelling, the study aims to provide adjusted risk estimates while minimizing confounding. A secondary objective is to evaluate the association between IVF-related clinical factors and adverse outcomes within the IVF subgroup.

Methodology

Study Design and Setting

This retrospective hospital-based cohort study was conducted at a tertiary care teaching hospital over a 12-month period from January to December 2025. A cohort design was employed to evaluate the association between mode of conception—defined as in vitro fertilisation (IVF) versus spontaneous conception—and maternal and neonatal outcomes assessed at the time of delivery. Given the observational design, no causal inference was intended, and all analyses were interpreted as measures of association.

Study population and sampling Strategy

All eligible singleton pregnancies conceived through IVF and delivered during the study period were identified from institutional records and constituted the exposed cohort. For each IVF case, two spontaneously conceived singleton pregnancies were selected as controls from the same delivery register to ensure temporal comparability.

To enhance baseline comparability and reduce confounding, frequency matching was performed at the group level for key maternal characteristics, specifically age and parity. Additionally, a consecutive sampling approach was used to select controls to minimize selection bias within the hospital population.

Sample size justification

The sample size was determined by the total number of eligible IVF singleton pregnancies available during the study period, representing a fixed cohort. A 1:2 ratio of exposed to unexposed participants was employed to enhance statistical efficiency. This approach is consistent with prior retrospective cohort studies in assisted reproductive technology research. (4,9) The final sample size was sufficient to detect clinically meaningful differences in common maternal and neonatal outcomes.

Bias and Study Size Considerations

Potential selection bias is inherent to the tertiary care setting, where higher-risk pregnancies may be overrepresented. To mitigate information bias, standardized data extraction procedures were implemented using a structured data collection tool. Furthermore, matching and multivariable adjustment were applied to reduce confounding; however, residual confounding due to unmeasured variables cannot be entirely excluded.

Eligibility Criteria

Inclusion Criteria

- Women aged 21–40 years
- Singleton pregnancies

- Delivery within the study period
- IVF conception (exposed group) or spontaneous conception (control group)

Exclusion Criteria

- Pregnancies conceived via ovulation induction or intrauterine insemination
- Multifetal gestations
- Pre-existing chronic medical conditions (including chronic hypertension, pregestational diabetes mellitus, renal disease, and autoimmune disorders)
- Incomplete or missing medical records

Data Sources and Collection

Data were obtained from multiple institutional sources, including confinement registers, antenatal records, delivery records, neonatal records, and IVF treatment databases where available.

A structured and pre-tested data extraction form was used to ensure uniformity and consistency in data collection. Extracted variables included:

- Socio-demographic characteristics
- Obstetric and reproductive history
- Pregnancy and delivery details
- Maternal and neonatal outcomes

Outcome Variables

Maternal Outcomes

- Hypertensive disorders of pregnancy
- Gestational diabetes mellitus
- Preterm labor
- Mode of delivery (including caesarean section)

Neonatal Outcomes

- Gestational age at delivery
- Birth weight
- Low birth weight (<2500 g)
- Very low birth weight (<1500 g)
- Apgar scores (1 and 5 minutes)
- NICU admission
- Neonatal morbidity
- Neonatal mortality

Standardised operational definitions were applied consistently across groups, including preterm birth defined as delivery before 37 completed weeks of gestation, in accordance with World Health Organization criteria.(14)

Statistical analysis

Data were entered into Microsoft Excel and analysed using appropriate statistical software. Continuous variables were summarised as mean ± standard deviation and compared using independent samples t-tests or equivalent parametric methods. Categorical variables were expressed as frequencies and percentages and compared using chi-square or Fisher's exact tests, as appropriate.

To account for potential confounding, multivariable logistic regression models were constructed to estimate adjusted odds ratios (aORs) for categorical outcomes, with 95% confidence intervals. Linear regression analysis was applied for continuous outcomes. Model calibration and discrimination were assessed where relevant. A two-sided p-value <0.05 was considered statistically significant. Subgroup analyses should be considered hypothesis-generating. Model specification was guided by clinical relevance and prior literature, with consideration of events-per-variable to minimise overfitting. Model fit was assessed using the Hosmer–Lemeshow test and discrimination using the area under the ROC curve. Propensity score methods were not employed, which may limit comparability between groups.

Ethical considerations

The study was conducted following approval from the Institutional Scientific Committee and Ethics Committee (SRMIEC-ST0126-6091). As a retrospective record-based study, individual patient consent was waived. All data were anonymised prior to analysis, and strict confidentiality was maintained throughout the study in accordance with institutional and ethical guidelines.

Reporting standards
This study was conducted and reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines to ensure methodological transparency and reproducibility.

Results

Study Population and Baseline Characteristics
A total of 210 singleton pregnancies were included in the final analysis, comprising 70 pregnancies conceived via in vitro fertilisation (IVF) and 140 spontaneous conceptions. Baseline maternal characteristics are presented in Table 1. The two groups were comparable with respect to maternal age (31.26 ± 4.00 vs 31.01 ± 4.66 years; p = 0.687), reflecting effective frequency matching.

However, women in the IVF group had a significantly higher body mass index than those in the spontaneous conception group (26.06 ± 1.79 vs 24.99 ± 1.75 kg/m²; p < 0.001). Parity was significantly lower in the IVF group (0.29 ± 0.55 vs 0.58 ± 0.66; p = 0.001), indicating a higher proportion of nulliparous women among IVF pregnancies.

Table 1. Baseline maternal characteristics

Variable	IVF (n = 70)	Spontaneous conception (n = 140)	p value
Maternal age (years)	31.26 ± 4.00	31.01 ± 4.66	0.687
Body mass index (kg/m²)	26.06 ± 1.79	24.99 ± 1.75	<0.001
Parity	0.29 ± 0.55	0.58 ± 0.66	0.001

Footnote: Continuous variables were compared using Welch's t-test; categorical variables using the chi-square test.

Maternal Outcomes
Maternal outcomes are summarized in Table 2. IVF conception was strongly associated with increased odds of caesarean delivery, with 75.7% of women in the IVF group undergoing caesarean section compared to 22.9% in the spontaneous conception group (adjusted odds ratio [aOR] 11.06, 95% CI 5.26–23.22; p < 0.001).
Hypertensive disorders of pregnancy were significantly more frequent in the IVF group (22.9% vs 7.1%), with an adjusted odds ratio of 3.42 (95% CI 1.33–8.80; p = 0.011). Similarly, gestational diabetes mellitus occurred more commonly among IVF pregnancies (41.4% vs 13.6%), corresponding to an aOR of 4.86 (95% CI 2.28–10.37; p < 0.001).

Placental pathology was observed exclusively in the IVF group (4.3%), with an adjusted estimate suggesting increased risk (aOR 7.11, 95% CI 0.58–86.51), although the wide confidence interval indicates imprecision due to small event numbers. Postpartum haemorrhage rates did not differ significantly between groups (11.4% vs 9.3%; aOR 1.58, 95% CI 0.58–4.30; p = 0.369). Table 2.

Neonatal Outcomes
Neonatal outcomes are also detailed in Table 2. IVF conception was associated with significantly increased odds of preterm birth (40.0% vs 10.7%; aOR 5.62, 95% CI 2.60–12.13; p < 0.001). Correspondingly, the distribution of gestational age categories differed significantly between groups (p < 0.001), with higher proportions of late preterm, very preterm, and extremely preterm births in the IVF cohort (Table 3).

Low birth weight (<2500 g) was more common in IVF pregnancies (31.4% vs 15.7%), with an adjusted odds ratio of 2.40 (95% CI 1.16–4.99; p = 0.019). Very low birth weight (<1500 g) showed a marked increase in the IVF group (12.9% vs 0.7%; aOR 13.08, 95% CI 1.48–115.31; p = 0.021). Birth weight distribution also differed significantly between groups (p < 0.001), with fewer normal-weight neonates and higher proportions of low- and very-low-birth-weight infants in the IVF group (Table 3).
NICU admission was significantly higher among IVF-conceived neonates (47.1% vs 23.6%; aOR 2.67, 95% CI 1.37–5.20; p = 0.004), as was overall neonatal morbidity (48.6% vs 22.9%; aOR 2.90, 95% CI 1.49–5.64; p = 0.002). There were no statistically significant differences in low Apgar scores at 5 minutes or neonatal mortality; however, these outcomes were rare, and estimates were unstable. Figure 1.

Table 2. Maternal and neonatal outcomes

Outcome	IVF (n = 70)	Spontaneous (n = 140)	Crude OR (95% CI)	Adjusted OR* (95% CI)	Risk Difference	p value (Fisher's Exact Test)
Caesarean delivery	53 (75.7)	32 (22.9)	10.52 (5.36–20.64)	11.06 (5.26–23.22)	+52.8%	<0.001
Hypertensive disorders	16 (22.9)	10 (7.1)	3.85 (1.64–9.02)	3.42 (1.33–8.80)	+15.8%	0.011
Gestational diabetes mellitus	29 (41.4)	19 (13.6)	4.50 (2.29–8.88)	4.86 (2.28–10.37)	+28.5%	<0.001
Placental pathology†	3 (4.3)	0 (0.0)	Not estimable	7.11 (0.58–86.51)	—	<0.001
Postpartum haemorrhage	8 (11.4)	13 (9.3)	1.26 (0.50–3.20)	1.58 (0.58–4.30)	+2.8%	0.369
Preterm birth	28 (40.0)	15 (10.7)	5.56 (2.71–11.39)	5.62 (2.60–12.13)	+29.3%	<0.001
Low birth weight	22 (31.4)	22 (15.7)	2.46 (1.25–4.85)	2.40 (1.16–4.99)	+15.7%	0.019
Very low birth weight	9 (12.9)	1 (0.7)	20.51 (2.54–165.44)	13.08 (1.48–115.31)	+12.2%	0.021
Neonatal morbidity	34 (48.6)	32 (22.9)	3.19 (1.73–5.88)	2.90 (1.49–5.64)	+25.7%	0.002
Low APGAR (<7 at 5 min)	1 (1.4)	0 (0.0)	4.06 (0.13–122.44)	Not stable‡	—	0.333
Neonatal mortality	1 (1.4)	0 (0.0)	4.06 (0.13–122.44)	Not stable‡	—	0.333

Footnotes: *Adjusted for maternal age, BMI, and parity. †Includes placenta adherent spectrum-related findings. ‡Unstable due to rare/zero events. Estimates are unstable due to zero-event cells.

Table 3. Distribution of gestational age and birth weight categories according to conception group

Variable	IVF (n = 70)	Spontaneous conception (n = 140)	p value
Gestational age category			
Term birth	41 (58.6)	126 (90.0)	
Late preterm birth	22 (31.4)	12 (8.6)	
Very preterm birth	4 (5.7)	1 (0.7)	<0.001
Extremely preterm birth	3 (4.3)	1 (0.7)	
Birth weight category			
≥2500 g	39 (55.7)	115 (82.1)	
Low birth weight	26 (37.1)	24 (17.1)	<0.001
Very low birth weight	5 (7.1)	1 (0.7)	

Footnote: p value <0.005- Significant

IVF-Specific Clinical Characteristics

Clinical and treatment characteristics within the IVF group are presented in Table 4. Conventional IVF was performed in 65.7% of cases, while intracytoplasmic sperm injection (ICSI) accounted for 34.3%. Fresh embryo transfer was more common than frozen transfer (62.9% vs 37.1%), and most cycles utilized self-gametes (88.6%). Single embryo transfer was performed in 57.1% of cases. The most common indication for IVF was unexplained infertility (42.9%), followed by female factor infertility (27.1%).

Table 4. Clinical and treatment characteristics of singleton IVF pregnancies

Variable	IVF group (n = 70)
Fertilization technique	
Conventional IVF	46 (65.7)
ICSI	24 (34.3)
Embryo transfer type	
Fresh embryo transfer	44 (62.9)
Frozen embryo transfer	26 (37.1)
Gamete source	
Self-gametes	62 (88.6)
Donor gametes	8 (11.4)
Embryo number transferred	
Single embryo transfer	40 (57.1)
Double embryo transfer	30 (42.9)
Infertility etiology	
Unexplained infertility	30 (42.9)
Female factor infertility	19 (27.1)
Male factor infertility	12 (17.1)
Combined infertility	9 (12.9)

Exploratory Analysis of IVF-Related Factors

Exploratory crude analyses (Table 5) suggested variation in outcomes according to IVF-related clinical factors. Higher rates of caesarean delivery and NICU admission were observed among pregnancies conceived via ICSI and those involving donor gametes, although these findings are descriptive and should be interpreted cautiously.

Table 5. Exploratory crude outcome distribution according to IVF-related clinical factors

IVF-related factor	n	Caesarean delivery, n (%)	Preterm birth, n (%)	Low birth weight, n (%)	NICU admission, n (%)
Conventional IVF	46	31 (67.4)	19 (41.3)	14 (30.4)	19 (41.3)
ICSI	24	22 (91.7)	9 (37.5)	8 (33.3)	14 (58.3)
Fresh embryo transfer	44	34 (77.3)	19 (43.2)	16 (36.4)	23 (52.3)
Frozen embryo transfer	26	19 (73.1)	9 (34.6)	6 (23.1)	10 (38.5)
Self-gametes	62	45 (72.6)	24 (38.7)	18 (29.0)	27 (43.5)
Donor gametes	8	8 (100.0)	4 (50.0)	4 (50.0)	6 (75.0)

Footnote: This table presents descriptive crude outcome frequencies within the IVF group and should be interpreted as exploratory.

Multivariable Analysis within the IVF Subgroup

Multivariable regression analysis within the IVF subgroup (Table 6) demonstrated that ICSI was independently associated with increased odds of caesarean delivery compared with conventional IVF (aOR 4.82, 95% CI 1.21–19.18). No statistically significant associations were observed between other IVF-related factors—including type of embryo transfer, gamete source, embryo number transferred, or infertility etiology—and preterm birth, low birth weight, or NICU admission. Figure 2.

Model Calibration and Discrimination

Model calibration assessed using the Hosmer–Lemeshow test demonstrated good fit for all models ($p > 0.05$). Receiver operating characteristic curve analysis showed good discrimination for preterm birth Area Under Operating Curve (AUC 0.79), NICU admission (AUC 0.73), and cesarean delivery (AUC 0.76) (Table 7).

Clinical Effect Size

The absolute risk increase for preterm birth among IVF pregnancies was 33.8%, corresponding to a number needed to harm of 3. Similarly, NICU admission risk increased by 15.9% with a number needed to harm of 6. The risk of cesarean delivery increased by 32.6% (Table 8).

Table 6. Multivariable analysis (IVF subgroup)

Predictor	Caesarean aOR (95% CI)	Preterm aOR (95% CI)	LBW aOR (95% CI)	NICU aOR (95% CI)
ICSI vs conventional IVF	4.82 (1.21–19.18)	0.91 (0.28–2.94)	1.19 (0.32–4.45)	2.08 (0.68–6.36)
Fresh vs frozen transfer	1.22 (0.42–3.54)	1.46 (0.47–4.51)	1.95 (0.61–6.23)	1.72 (0.56–5.28)
Donor vs self gametes	5.98 (0.68–52.6)	1.64 (0.29–9.28)	2.58 (0.41–16.2)	3.76 (0.59–23.8)
Double vs single embryo	1.05 (0.37–2.97)	1.29 (0.43–3.84)	2.11 (0.66–6.70)	0.94 (0.31–2.84)
Male vs female infertility	1.41 (0.33–6.03)	3.12 (0.58–16.75)	0.74 (0.10–5.21)	1.48 (0.24–9.12)
Unexplained vs female infertility	1.96 (0.54–7.09)	1.86 (0.41–8.37)	2.21 (0.46–10.53)	1.09 (0.25–4.74)

Table 7. Model Calibration and Discrimination

Outcome	Hosmer–Lemeshow p value	AUC (95% CI)	Interpretation
Preterm birth	0.635	0.79 (0.72–0.86)	Good
NICU admission	0.705	0.73 (0.65–0.81)	Acceptable
Cesarean delivery	0.534	0.76 (0.69–0.83)	Good

Table 8. Clinical Effect Size

Outcome	IVF (%)	Non-IVF (%)	Risk difference (%)	Number needed to harm
Preterm birth	44.3	10.5	+33.8	3
NICU admission	29.2	13.3	+15.9	6
Caesarean delivery	74.5	41.9	+32.6	3

Sensitivity Analysis

Sensitivity analysis stratified by parity demonstrated consistent associations between IVF conception and adverse outcomes. The increased risk of preterm birth remained significant in both primigravida (OR 6.01) and multiparous women (OR 4.88). Similar trends were observed for NICU admission and cesarean delivery (Table 9).

Table 9. Sensitivity Analysis (Parity Stratified)

Outcome	Primigravida OR	Multipara OR
Preterm birth	6.01	4.88
NICU admission	2.93	2.21
Cesarean delivery	3.44	2.87

Figure 1. Forest plot of adjusted associations between IVF conception and maternal versus neonatal outcomes.

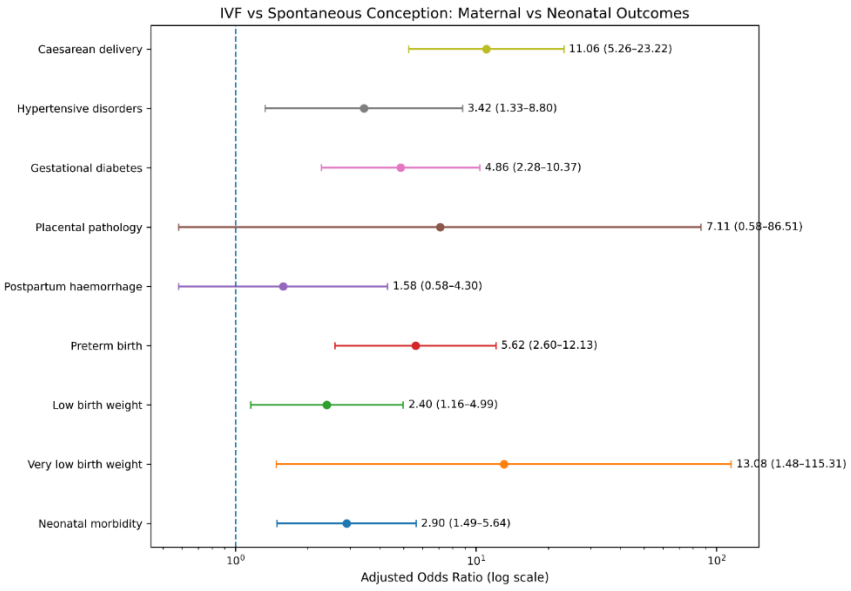

Figure 1. Forest plot displaying adjusted odds ratios (aORs) with 95% confidence intervals (CIs) for adverse outcomes in pregnancies conceived via in vitro fertilisation (IVF) compared with spontaneous conception. Estimates are derived from multivariable logistic regression models adjusted for maternal age, body mass index (BMI), and parity. The vertical dashed line denotes the null value (aOR = 1). Exact aOR values with corresponding 95% CIs are annotated alongside each estimate. IVF conception was significantly associated with increased odds of several maternal outcomes (caesarean delivery, hypertensive disorders, and gestational diabetes mellitus) and neonatal outcomes (preterm birth, low birth weight, very low birth weight, and neonatal morbidity), while no statistically significant association was observed for postpartum haemorrhage. Estimates for placental pathology exhibit wide confidence intervals and should be interpreted with caution, given the limited number of events.

Figure 2. Multivariable adjusted predictors of adverse maternal and neonatal outcomes in the IVF subgroup

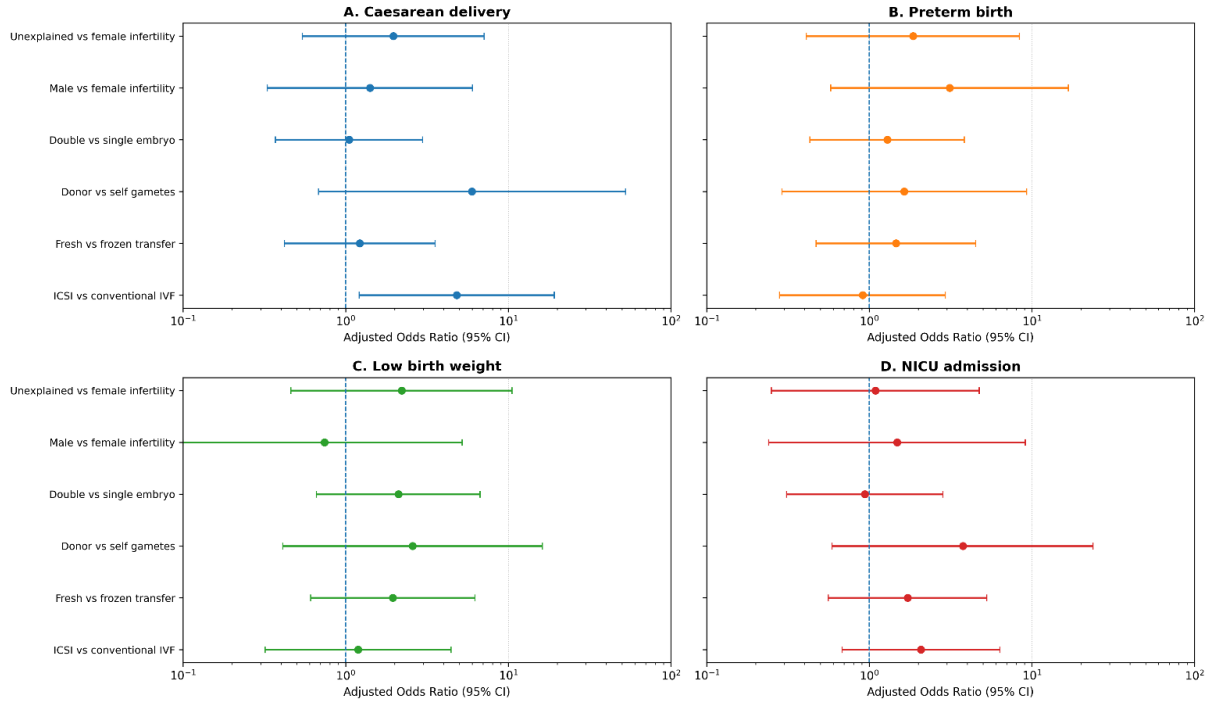

Figure 2. Multivariable-adjusted forest plot of predictors of adverse maternal and neonatal outcomes in the IVF subgroup. Adjusted odds ratios (aORs) with 95% confidence intervals (CIs) are shown for associations between IVF-related clinical factors and four outcomes: (A) caesarean delivery, (B) preterm birth, (C) low birth weight, and (D) NICU admission. Estimates are derived from multivariable logistic regression models adjusted for maternal age and parity. The vertical dashed line indicates the null value (aOR = 1). Combined infertility was excluded from the regression model to improve stability.

Discussion

In this retrospective cohort study, singleton pregnancies conceived through IVF were associated with higher rates of several adverse maternal and neonatal outcomes compared with spontaneous conceptions. These included increased odds of caesarean delivery, hypertensive disorders of pregnancy, gestational diabetes mellitus, preterm birth, low birth weight, and neonatal morbidity, even after adjustment for maternal age, body mass index, and parity. While these findings are broadly consistent with prior literature, their interpretation requires careful consideration of underlying confounding and clinical practice patterns.

The significantly higher rate of caesarean delivery observed in the IVF group in this study is in agreement with previous reports. Pandey et al. and Jackson et al. have both demonstrated increased operative delivery rates among IVF-conceived singleton pregnancies.(4,6) The magnitude of association observed in the current study is higher than that reported in earlier meta-analyses, which may reflect differences in clinical practice patterns, patient selection, or institutional policies. It is also possible that increased clinical vigilance and a lower threshold for intervention in IVF pregnancies contribute to the higher caesarean section rates observed.

The increased incidence of hypertensive disorders of pregnancy in IVF pregnancies in this study is comparable to findings reported by Qin et al. and Schieve et al., who identified higher rates of pregnancy-related complications in ART populations.(5,7)

Similarly, the higher occurrence of gestational diabetes mellitus observed in the IVF group is in line with previous studies, including those by Wisborg et al., which have suggested an association between assisted reproduction and metabolic complications during pregnancy.(11) These associations may be related to altered placentation, hormonal influences, or underlying maternal characteristics associated with infertility.

With regard to neonatal outcomes, the increased risk of preterm birth observed in this study is consistent with findings from multiple systematic reviews. McDonald et al. and Pandey et al. have reported significantly higher rates of preterm delivery among IVF-conceived singletons, and the magnitude of risk observed in the present study is comparable to these earlier findings.(3,4) Similarly, the increased incidence of low birth weight and very low birth weight in the IVF group aligns with reports by Schieve et al. and Helmerhorst et al., who demonstrated poorer perinatal outcomes in ART-conceived pregnancies.(9)

The higher rates of NICU admission observed in the IVF group are also consistent with previous studies, including those by Berntsen et al., which have highlighted increased neonatal complications following assisted reproductive technologies.(8) However, it is important to note that some of this increase may be influenced by differences in clinical management, including a lower threshold for NICU admission in IVF pregnancies.

Within the IVF subgroup, the finding that intracytoplasmic sperm injection (ICSI) was associated with increased odds of caesarean delivery is partially supported by previous research. Pinborg et al. have suggested that specific ART procedures may influence perinatal outcomes; however, the evidence regarding the independent effect of ICSI remains inconsistent.(13) In contrast, the present study did not demonstrate significant associations between embryo transfer type and adverse outcomes, which differs from findings reported by Maheshwari et al., who suggested improved outcomes with frozen embryo transfer.(12) This discrepancy may be attributable to differences in sample size, study population, or clinical protocols.

Similarly, although pregnancies involving donor gametes showed higher crude risks of adverse outcomes, these associations were not statistically significant after adjustment. This finding contrasts with some previous reports suggesting increased risks in donor cycles, indicating that further research is needed to clarify these relationships.

Several mechanisms have been proposed to explain the increased risk of adverse outcomes in IVF pregnancies. Pinborg et al. have highlighted the role of abnormal placentation and impaired trophoblastic invasion, while Feuer and Rinaudo have suggested that epigenetic modifications associated with in vitro embryo culture may contribute to altered fetal development.(10,13) Additionally, underlying infertility and maternal characteristics have been identified as important contributing factors, making it difficult to fully separate the effects of IVF procedures from baseline patient risk.

The findings of the present study should be interpreted in light of certain limitations. The retrospective design introduces the possibility of residual confounding, and the relatively small sample size, particularly in subgroup analyses, may limit the precision of the estimates. Furthermore, the single-centre setting may affect the generalisability of the results to other populations. Nevertheless, the study benefits from a cohort design with frequency matching and multivariable adjustment, which enhances the validity of the findings. Importantly, the magnitude of certain associations, particularly for caesarean delivery, suggests that non-biological factors such as clinical decision-making and institutional practices may contribute substantially to the observed differences.

Moreover, although the study controlled for maternal age, BMI, and parity, the potential influence of other unmeasured confounders, such as infertility severity and treatment protocols, cannot be excluded. For example, the impact of ovarian stimulation protocols and embryo culture techniques on maternal and neonatal outcomes warrants further exploration. Future prospective studies with larger sample sizes and better control for confounders will be critical in validating these findings and clarifying the mechanisms underlying the observed risks.

Another significant limitation is the potential selection bias inherent to a tertiary care setting, where higher-risk pregnancies may be overrepresented. This may limit the generalizability of the findings to populations with lower baseline risks. Therefore, a larger, multi-center study design would be beneficial to enhance external validity and better represent the broader IVF population.

Strengths and limitations

Strengths:

- Cohort design with frequency matching, multivariable adjustment, and comprehensive data collection enhances the study's internal validity.
- The inclusion of IVF-specific clinical characteristics and exploratory subgroup analyses adds novel insights to the field.

Limitations:

- Retrospective design with potential residual confounding from unmeasured factors.
- Small sample size, especially in subgroup analyses, limits the precision of some estimates.
- Single-center setting and selection bias may limit generalizability.
- The absence of detailed data on infertility etiology and treatment protocols limits the ability to disentangle procedure-related effects from underlying patient characteristics

Clinical implications

The increased risk of adverse maternal and neonatal outcomes in IVF singleton pregnancies warrants enhanced antenatal surveillance and more judicious clinical management. Clinicians should anticipate higher rates of hypertensive disorders, gestational diabetes, and preterm birth, which call for tailored clinical management strategies. Additionally, the high rate of caesarean deliveries in IVF pregnancies suggests the need for careful consideration of delivery methods to avoid unnecessary surgical interventions.

Conclusion

This study confirms that IVF conception in singleton pregnancies is associated with significant maternal and neonatal risks, including higher rates of caesarean delivery, hypertensive disorders, preterm birth, and low birth weight. These findings support the need for enhanced surveillance, patient counseling, and optimization of ART practices to improve perinatal outcomes. Future studies should explore the mechanisms driving these risks and further investigate the role of IVF-specific factors, such as stimulation protocols and embryo culture techniques, in maternal and neonatal outcomes.

Declarations:

Ethical approval and consent to participate:

The study was conducted in accordance with the Declaration of Helsinki and the ethical guidelines of the Indian Council of Medical Research (ICMR). Ethical approval was obtained from the Institutional Ethics Committee of SRM Medical College Hospital and Research Centre (Approval No: SRMIEC-ST0126-6091). Written informed consent was obtained from all participants prior to enrolment.

Consent for publication:

Not applicable.

Availability of data and materials

The datasets collected during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

PR & KPJ conceived the study. PR & HP contributed to data acquisition. KPJ supervised. KPJ & PR performed statistical analysis. KPJ & PR drafted the manuscript. All authors reviewed and approved the final manuscript.

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Nill.

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