RESEARCH PAPER

Predictors of Clinical Pregnancy in Assisted Reproductive Technology: A Comparative Analysis of Fresh and Frozen Embryo Transfer Cycles

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ABSTRACT

The success of assisted reproductive technology (ART) procedures is a combination of biological and procedural factors and it is not easy to know whether the treatment would be successful. Clinical pregnancy is an important measure of ART efficacy and this needs to be assessed using combined methods of analysis. Institutional data of 94 embryo transfer cycles based on an original sample of 1095 ART cycles was used to carry out an observational retrospective study. The embryo transfer cycle was considered to be the unit of analysis. The variables considered were female age, male age, type of cycle (fresh and frozen), type of embryo transfer (single and double), and sperm selection method. The overall pregnancy rate was 61.7. No statistically significant difference was found in the fresh embryos transfer cycles and the frozen embryos transfer cycles. In the multivariate analysis, the only independent predictor was the incidence of pregnancy, which was better with the use of double embryo transfer compared to single embryo transfer. There was no independent association of results with other variables, such as age and sperm preparation method. The predictive model was moderate in the discriminative ability. These results demonstrate the relevance of embryo transfer plan in determining the success of ART, and affirm the similarity of fresh and frozen cycles. More research with more comprehensive biological variables is needed to increase predictive validity.

KEYWORDS: Assisted Reproductive Technology, Clinical Pregnancy, Embryo Transfer, Frozen Embryo Transfer, Predictive Modeling

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1. INTRODUCTION

The issue of infertility is an acute issue among the world population and it plagues millions of people and couples. Not only is it associated with biological and reproductive problems but it can also be extremely costly psychologically, socially and economically. Recent world estimates have recorded a high level of infertility in both developed and developing world and this has been a factor contributing to the high level of infertility in the reproductive health systems (Sun et al., 2019). Also, the demographic studies performed in the past have revealed the rising trends of primary and secondary infertility and the necessity to develop better diagnostic and treatment strategies (Mascarenhas et al., 2013). Moreover, the issue of the definition of infertility, especially when it comes to the unexplained infertility, also makes the clinical management and standardization of research more difficult (Raperport et al., 2024).

Assisted reproductive Technology (ART) has emerged as one of the pillars of treatment of infertility which provides effective treatment of most of the reproductive disorders. Nowadays, ART is already an experimental treatment in the past four decades, and its laboratories, cryopreservation, and embryo transfer techniques have evolved significantly (Takhar and Houston, 2021). Regardless of these developments, the results of ART are still inconsistent and depend on the complex interaction of demographic, biological, and procedural factors. This inconsistency highlights the importance of better comprehending the determinants of treatment success, especially clinical pregnancy, an important intermediate outcome in ART cycles.

The process of embryo implantation is highly coordinated, extremely complex and on its own, the success of ART relies on the process. The implantation is a complex of cellular and molecular interactions between the embryo and the endometrium that is known as a paradox due to the strongly regulated and dynamical process (Denker, 1993). The idea of the endometrial receptivity is one of the key elements of this process, as it justifies the temporary nature of the endometrium that is most probably to undergo embryo adherence and intrusion (Lessey and Young, 2019). The involvement of molecular regulators, such as HOXA10 and HOXA11

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genes, has been proposed in the process of endometrial activities and pregnancy outcomes, which further highlights the biological complexity of successful implantation (Pirlog et al., 2025).

Other factors that have been highly studied with regard to ART are endometrial characteristics. The endometrial thickness has been referred as the key factor that shows successful implantation but no conclusive evidence has shown that endometrial thickness is a predictive factor. Other scholars have opined that no particular threshold can be used to establish an independent connection between a positive relationship between increased endometrial thickness and increased pregnancy rates (Yuan et al., 2016; Shakerian et al., 2021), even though other authors have found that there is a positive relationship between these two variables. This variability suggests that there can not be a single parameter that can explain implantation success and that it is a multifactorial process with embryonic and endometrial factors.

Another crucial success factor in ARTs is sperm quality which determines fertilization and subsequent embryo development. Sperm DNA integrity defects are linked to impairments in spermatogenesis, which can have a negative impact on embryo viability and implantation potential (Kuchakulla et al., 2021). This is relevant to the methods of sperm selection, in order to maximize the fertilization process, by isolating functionally competent spermatozoa. Nevertheless, how various sperm preparation techniques have independent effects on clinical pregnancy is a field of current research.

In addition to biological variables, procedures variables, e.g. embryo transfer strategy, are an influential outcome determinant of ART. Embryo transfer is directly proportional to the likelihood of implantation and in most cases, the likelihood of implantation is higher with the transfer of two embryos as compared to that of one embryo. However, this approach will have to be modified to the increased risk of multiple gestations. Likewise, fresh and frozen embryo transfer cycles too have also received much controversy. Advancements in the area of cryopreservation have opened additional opportunities to the survival of frozen embryos, and current findings suggest that the findings of fresh and frozen transfers could be the same in the best case (Zaat et al., 2021). However, the relative importance of these procedural factors in integrated predictive models is not well studied.

A number of other challenges especially in the low and middle income countries render it difficult to carry out a large-scale clinical study in the field of reproductive medicine. The quality of data might vary, and the record-keeping discrepancy might affect the reliability and generalizability of the findings, and be limited by a longitudinal follow-up (Anjana et al., 2023). The issues are particularly relevant to retrospective studies in which data completeness and standardization are crucial to a good study.

Considering this, combined approaches of analysis to measure different determinants of ART outcomes in clinical datasets in real life is needed. The current paper will be focused on an evaluation of the predictors of clinical pregnancy in embryo transfer cycles with a particular focus on demographics, procedures and laboratory variables. The study aims to offer a systematic review of the factors affecting the success of ART and help to build more all-encompassing predictive models by concentrating on the cycle-level analysis and including both fresh and frozen embryo transfer cycles. The objectives of this study are:

- To identify independent predictors of clinical pregnancy in assisted reproductive technology (ART) cycles at the embryo transfer level.
- To compare clinical pregnancy outcomes between fresh and frozen embryo transfer cycles.
- To evaluate the association between embryo transfer type (single vs double embryo transfer) and clinical pregnancy.
- To assess the relationship between sperm selection technique and clinical pregnancy outcomes.
- To examine the effect of demographic factors (female and male age) on clinical pregnancy.
- To develop and evaluate a multivariate model for predicting clinical pregnancy in ART cycles.

2. MATERIALS AND METHODS

2.1 Study Design

This research was carried out as a retrospective analysis study which involved observation to identify the predictors of clinical pregnancy in assisted reproductive technology (ART) cycles. The review of institutional records kept regularly based on the years was used to analyze the results. The right type of design was retrospective design because it entailed use of data on clinical and laboratory findings that were already available and would not disrupt decisions of treatment and patient management. The analytical objective was to evaluate the association between the chosen demographic variables, procedural variables, and laboratory-related variables and clinical outcome of pregnancy. The embryo transfer cycle was viewed as the primary unit of analysis as the outcome of the pregnancy could be associated with the particular transfer events.

2.2 Study Setting

The experiment in this case was done in a tertiary reproductive medicine hospital which offered in vitro fertilization (IVF) and intracytoplasmic sperm injection (ICSI) services. There were institutional records of ovarian stimulation, fertilization procedures, embryo transfer, sperm preparation procedures and clinical outcomes maintained in the center. The time period of the research was 2022 (March) to 2025 (December). The retrospective data extraction was done through the available records which were the source of clinical and laboratory procedures done as per institutional practice. Clinical setting provided a chance to assess the outcomes of ART in a setting, which resembles clinical practice during fresh and frozen embryo transfer cycles.

2.3 Study Population and Sampling

The first institutional datasets were found to contain 1095 ART cycles. These were made up of various treatment cycles that comprised of stimulation cycles, fertilization processes, vitrification processes, thawing processes and embryo transfer processes. The systematic cleaning and screening made only valid embryo transfer cycles with complete and analyzable information remain. The last analytical sample consisted of 94 embryo transfer cycles. The separate calculation of the sample size was not conducted in the study because it used all the eligible records that were available during the study. All were present including fresh embryo transfer and frozen embryo transfer (FET) cycles such that a comparative analysis of pregnancy outcomes can be done across cycles.

2.4 Eligibility Criteria

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2.5 Data Source and Data Processing

Institutional clinical and lab records were used to extract data and were combined into one analytical dataset. A lot of preprocessing was required to enhance consistency and reliability. Duplicates and records which were not structurally consistent and redundant were eliminated. DataSets were normalized with regard to variable names, formats and category names. The free-text entries in the field of embryo transfer and sperm preparation were updated and coded into categories that were able to be analyzed. One observation in the last dataset was termed as the embryo transfer cycle. Those records without valid transfer information or outcome information were excluded. This preprocessing minimized the misclassification, increased the internal consistency and fit the dataset to the statistical analysis.

2.6 Variables Studied

The dependent variable was clinical pregnancy, which was a binary variable. The independent variables were age of females, age of males, type of cycle (fresh or frozen embryo transfer), type of embryo transfer (single embryo transfer [SET] or two embryos transfer [DET]) and the sperm selection method. The existing literature was employed to categorise sperm preparation into a double density gradient (DDG) or no (non-DDG/ unknown) group. Live birth was regarded as a secondary outcome in sites of this study but its analysis was compromised due to a lack of full follow up. Variables were chosen by how they were available in the final cleaned dataset and how they are clinically relevant to ART outcome assessment.

2.7 Outcome Measures

The primary outcome of the study was clinical pregnancy. This was evaluated based on institutional documents of positive pregnancy outcome after embryo transfer. The variable was coded dichotomously (pregnancy achieved and no pregnancy) to analyse. Live birth was considered a secondary outcome, and was coded where it was specifically coded in the follow-up listing. However, because of unrecorded full data on live births and extremely minimal amounts of events recorded, no detailed inferential analysis was done on live birth but descriptive analysis was done. Hence, clinical pregnancy was the main statistical modeling and interpretation endpoint.

2.8 Statistical Analysis

StatSPSS version 22 was used to conduct statistical analysis. Continuous variables were described in terms of mean and standard deviation, whereas the frequencies and percentages were used to describe categorical variables. The independent samples t-test of continuous variables and the Chi-square test of categorical variables were the baseline comparisons of fresh and frozen cycles. Univariate analysis was used to evaluate the relationship between cycle type, transfer type and sperm selection technique and clinical pregnancy. Multivariate logistic regression analysis was done to determine independent predictors of clinical pregnancy. The likelihood ratio test was used to evaluate model fit and receiver operating characteristic (ROC) curve analysis and area under the curve (AUC) were used to evaluate predictive performance.

3. RESULTS

3.1 Study Population and Baseline Characteristics

A total of 1095 ART cycles were initially identified from institutional records. Following data cleaning and validation, and inclusion criteria issues, 94 embryo transfer cycles were included in the final study. All the cycles were clinical events that could be evaluated based on outcomes (Table 1). The mean female age was 29.63 ± 4.35 years, and the mean male age was 35.77 ± 4.91 years.

Most (81.9) of embryo transfer cycles were performed with frozen embryos (FET), and just 18.1 with fresh cycles. DET was done on 83 percent of cycles and single embryo transfer (SET) on 17 percent. The most used method of sperm preparation was the double density gradient (DDG) (91.5% of the total) (Figure 1, 2 and 3).

Table 1. Baseline Characteristics of the Study Population (n = 94)

Variable	**Value**
Female Age (years)	29.63 ± 4.35
Male Age (years)	35.77 ± 4.91
Cycle Type	
Frozen (FET)	81.9%
Fresh	18.1%
Transfer Type	
DET	83%
SET	17%
Sperm Method	
DDG	91.5%
Unknown	8.5%

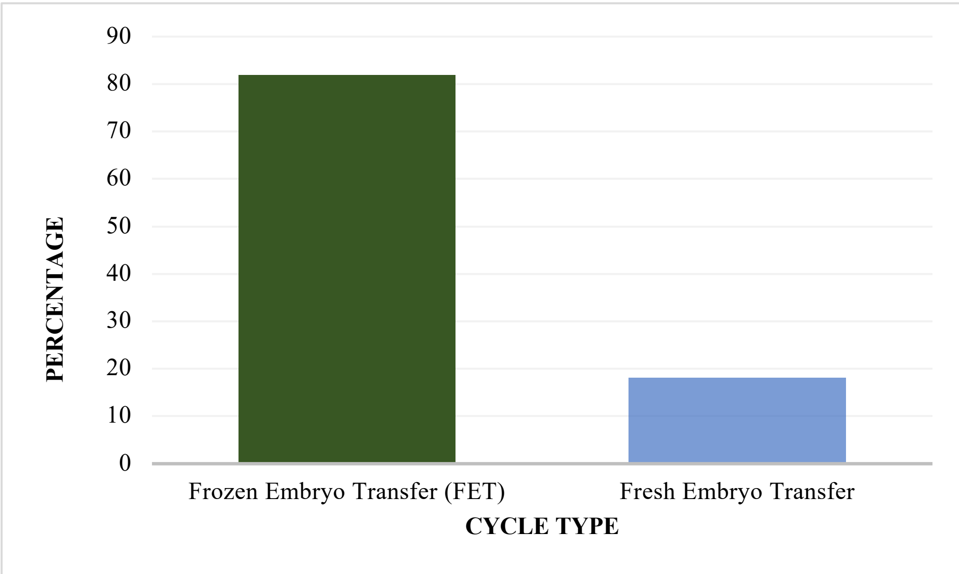

Figure 1. Distribution of fresh and frozen embryo transfer cycles

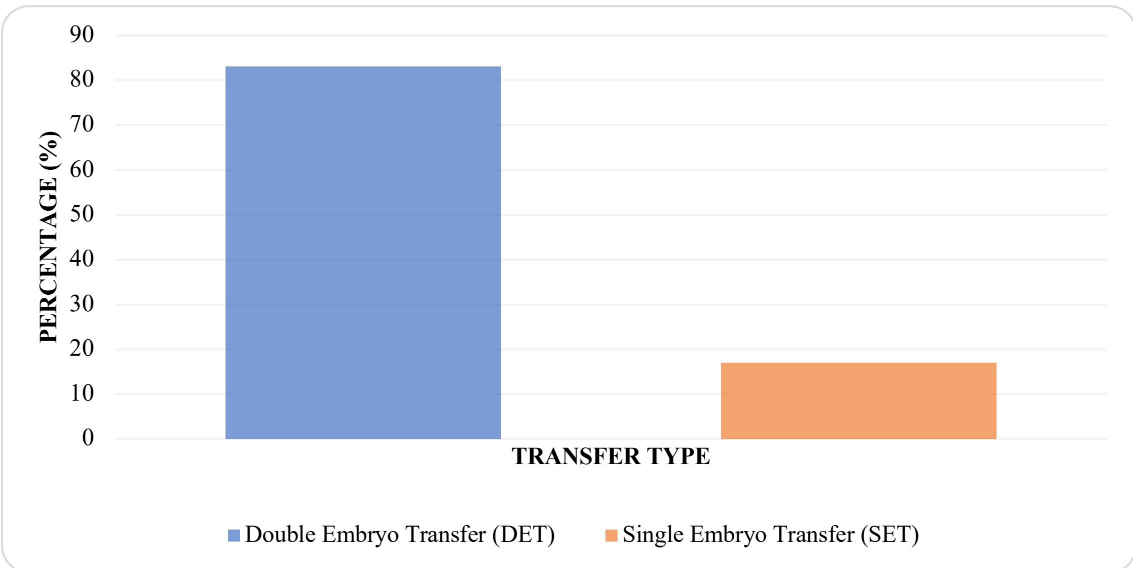

Figure 2. Distribution of single vs double embryo transfer

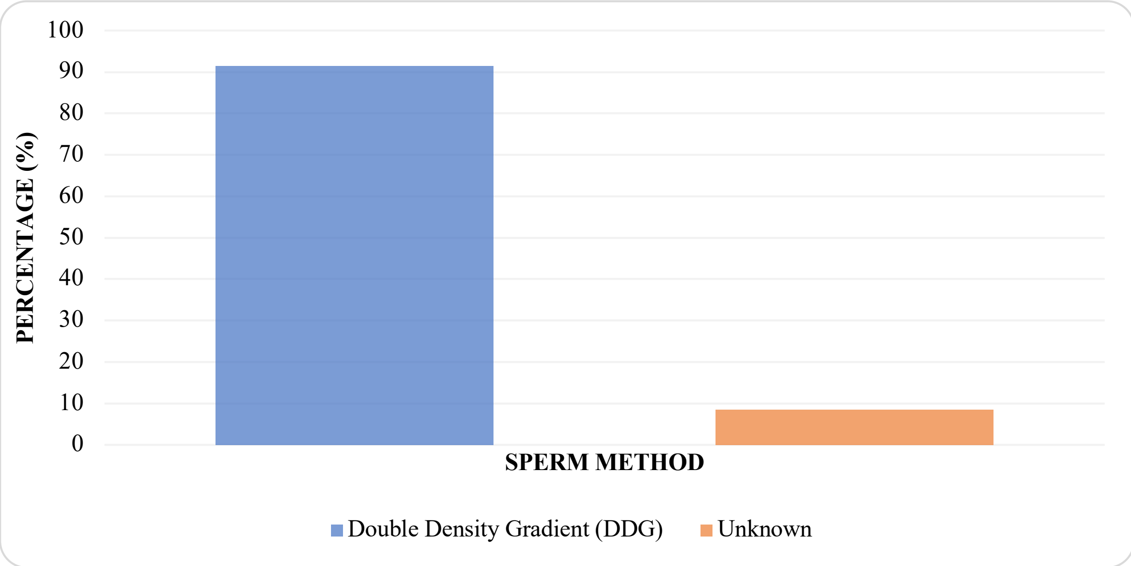

Figure 3. Distribution of sperm selection techniques

These findings indicate a cohort predominantly composed of FET cycles with high utilization of DET and DDG techniques.

3.2 Comparison Between Fresh and Frozen Embryo Transfer Cycles

Comparative analysis showed that there were no statistically significant differences in the fresh and frozen cycles in the baseline characteristics. The mean female age (28.88 ± 4.17 vs 29.80 ± 4.41 years; p = 0.46) and male age (36.44 ± 4.78 vs 35.62 ± 4.94 years; p = 0.59) were comparable between groups (Table 2).

DET was predominant in both groups (94.1% in fresh vs 80.5% in FET; p = 0.32). In the same way, all fresh cycles and 89.6% of FET cycles (p = 0.36) used DDG as indicated in Figure 4 and Figure 5.

Table 2. Comparison of Baseline Characteristics Between Fresh and FET Cycles

Variable	Fresh (n=17)	FET (n=77)	p-value
Female Age	28.88 ± 4.17	29.80 ± 4.41	0.46
Male Age	36.44 ± 4.78	35.62 ± 4.94	0.59
DET	94.1%	80.5%	0.32
SET	5.9%	19.5%	
DDG	100%	89.6%	0.36
Unknown	0%	10.4%	

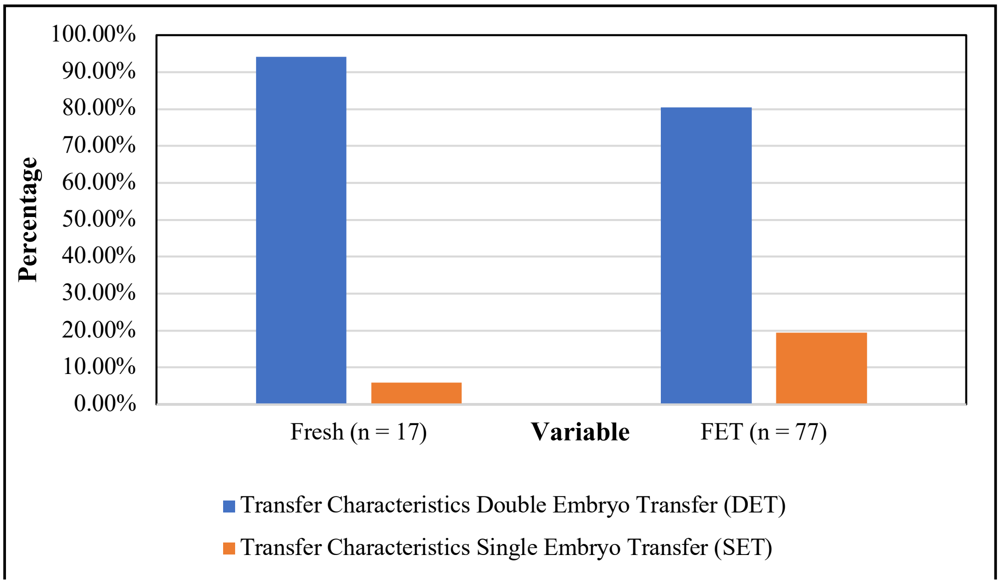

Figure 4. Transfer type distribution across cycle types

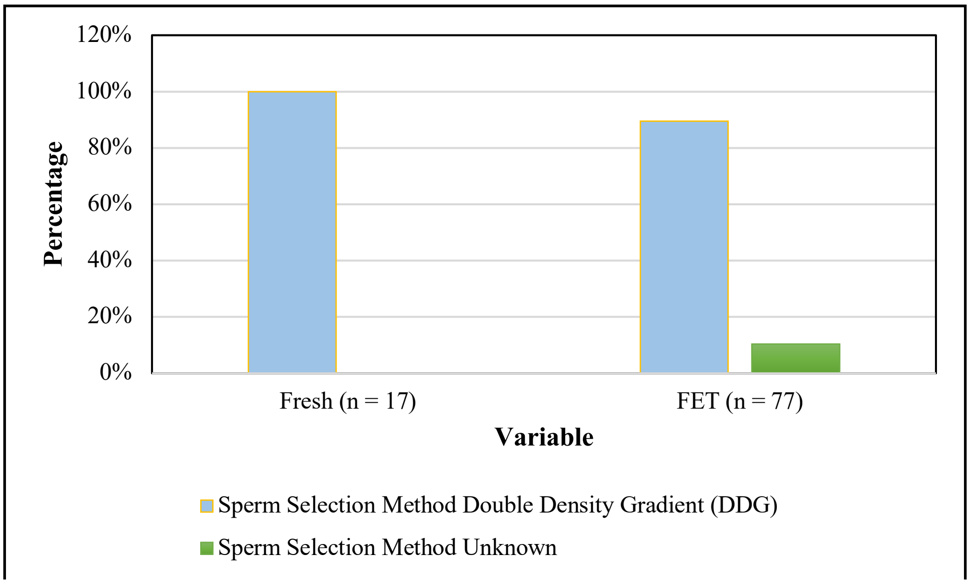

Figure 5. Sperm method distribution across cycle types

3.3 Clinical Outcomes

3.3.1 Clinical Pregnancy

A total of 61.7% (58/94 cycles) was the overall clinical pregnancy rate, as shown in Table 3. FET cycles were successful in pregnancy (62.3 and fresh cycles 58.8) (Figure 6). The variation was not significant (p = 1.00) which shows that the results were similar.

Table 3. Clinical Pregnancy Outcomes by Cycle Type

Outcome	Fresh (n=17)	FET (n=77)	Total (n=94)	p-value
Pregnancy	10 (58.8%)	48 (62.3%)	58 (61.7%)	1.00
No Pregnancy	7 (41.2%)	29 (37.7%)	36 (38.3%)	

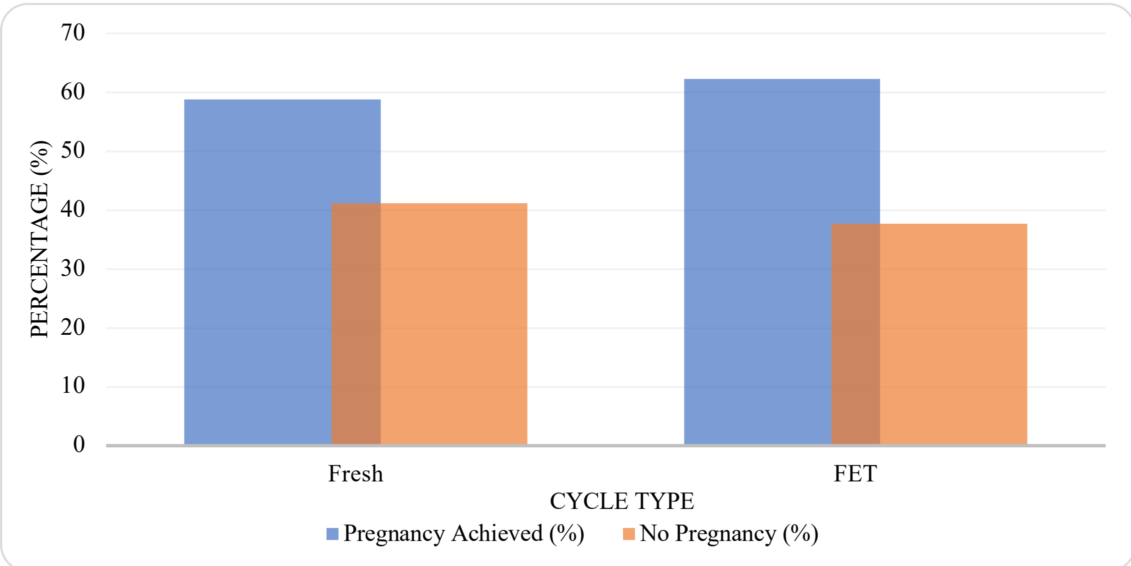

Figure 6. Clinical pregnancy comparison between fresh and FET cycles

3.3.2 Live Birth Outcomes

Only one live birth (1.1%) was recorded among 94 cycles, while 93 cycles (98.9%) had no documented live birth (Table 4 and Figure 7)).

Table 4. Live Birth Outcomes

Outcome	n (%)
Live Birth	1 (1.1%)
No Live Birth	93 (98.9%)

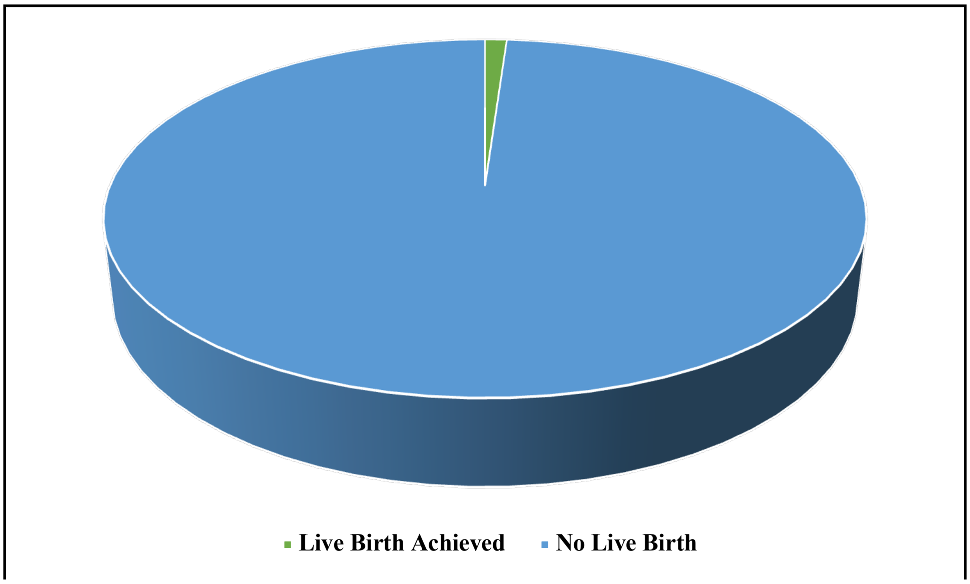

Figure 7. Distribution of live birth outcomes

3.4 Univariate Analysis

3.4.1 Cycle Type

No association was observed between cycle type and clinical pregnancy (p = 1.00), as shown in Table 5.

Table 5. Cycle Type vs Clinical Pregnancy

Outcome	Fresh	FET	p-value
Pregnancy	58.8%	62.3%	1.00
No Pregnancy	41.2%	37.7%	

3.4.2 Transfer Type

DET showed higher pregnancy rates (66.7%) compared to SET (37.5%), with borderline significance (p = 0.057), as shown in Table 6.

Table 6. Transfer Type vs Clinical Pregnancy

Outcome	SET (n=16)	DET (n=78)	p-value
Pregnancy	37.5%	66.7%	0.057
No Pregnancy	62.5%	33.3%	

3.4.3 Sperm Selection Technique

DDG cycles showed significantly higher pregnancy rates (66.3%) compared to others (12.5%) (p = 0.009), as presented in Table 7 and Figure 8-11.

Table 7. Sperm Method vs Clinical Pregnancy

Outcome	DDG (n=86)	Others (n=8)	p-value
Pregnancy	66.3%	12.5%	0.009
No Pregnancy	33.7%	87.5%	

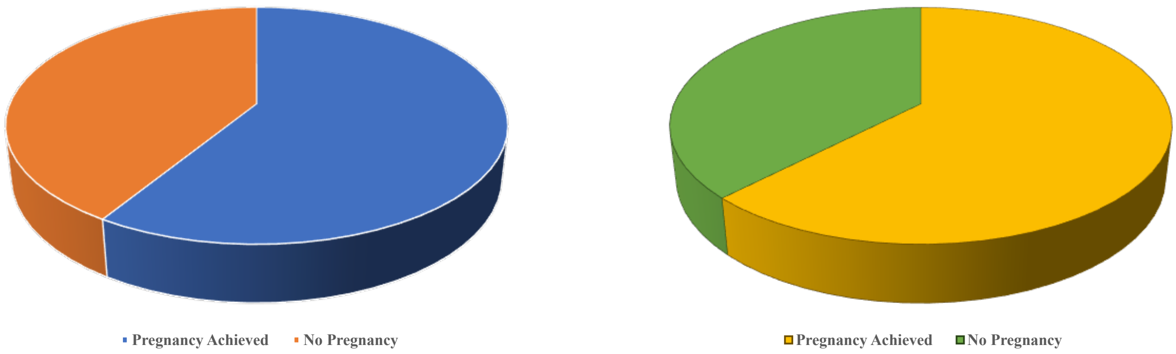

Figure 8: Comparative Distribution of Clinical Pregnancy Outcomes in Fresh and Frozen Embryo Transfer Cycles

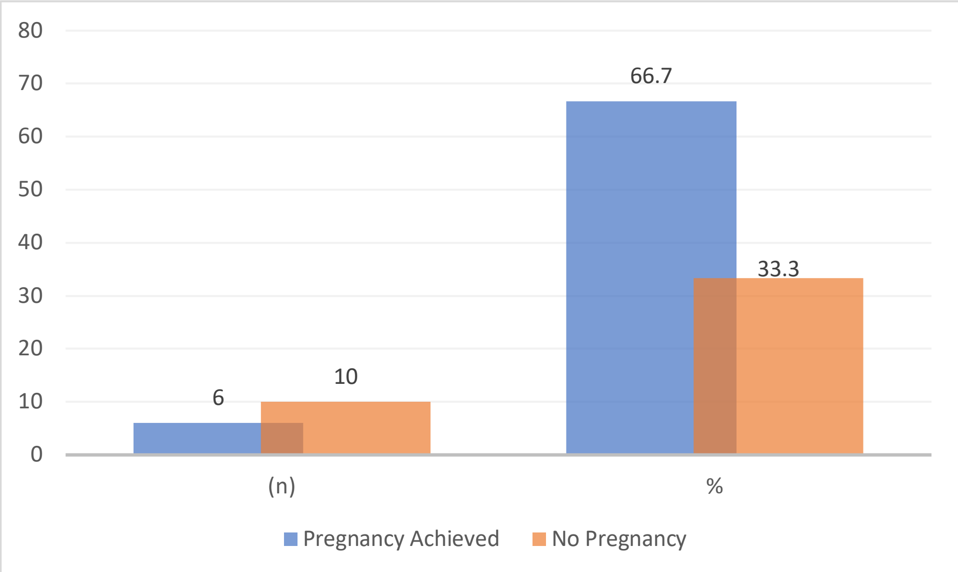

Figure 9: Clinical Pregnancy Outcomes According to Embryo Transfer Type (SET)

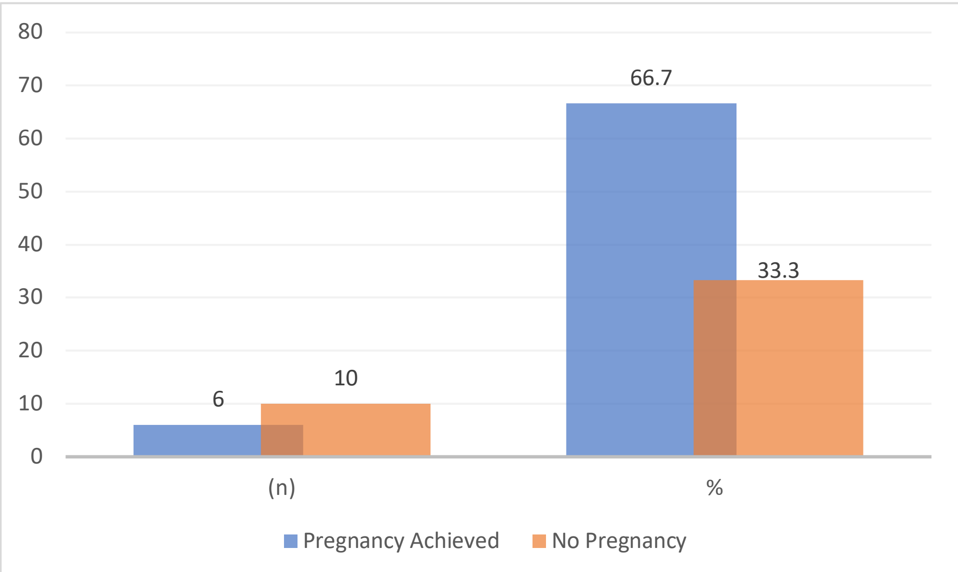

Figure 10: Clinical Pregnancy Outcomes According to Embryo Transfer Type (DET)

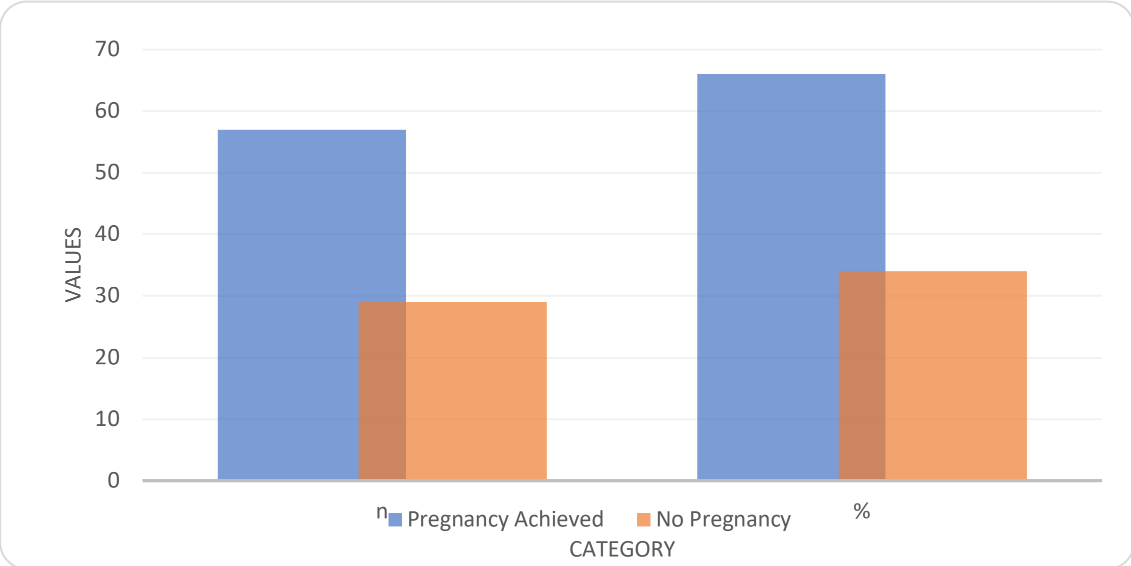

Figure 11: Clinical Pregnancy Outcomes According to Sperm Selection Method (DDG)

3.5 Multivariate Analysis

Multivariate logistic regression identified embryo transfer type as the only independent predictor of clinical pregnancy.

Table 8. Multivariate Logistic Regression Analysis

Variable	Adjusted OR	95% CI	p-value
Female Age	0.975	0.851–1.118	0.720
Male Age	0.934	0.832–1.048	0.246
SET vs DET	0.249	0.067–0.922	0.037
Fresh vs FET	0.480	0.145–1.590	0.230
Unknown vs DDG	0.154	0.013–1.756	0.132

SET was associated with significantly lower odds of pregnancy compared to DET.

4. DISCUSSION

The current research assessed the clinical pregnancy predictors of assisted reproductive technology (ART) cycles with the help of a retrospective analysis model and took into consideration the occurrence of embryo transfer. The results indicate that of the variables considered, embryo transfer type was the sole independent predictor of clinical pregnancy with double embryo transfer (DET) showing a significant improvement of the chance of success as compared to single embryo transfer (SET). Conversely, there were no statistically significant independent relationships that were identified in the type of cycle (fresh or frozen), method of sperm selection and demographic variables including age of females and males. These results would indicate the preponderance of procedural issues especially the embryo transfer policy in deciding the outcome of ARTs among the respondents group in this experiment.

The fact that DET is related to much greater odds of clinical pregnancy is biologically plausible and in line with the probabilistic nature of implantation. The transfer of more than one embryo will increase the chances of at least one embryo to implant and improve the overall pregnancy rates. This was not only observed in a multivariate analysis where SET had a significantly lower odds (OR = 0.249), but also as a significant trend in a univariate analysis. This discovery, however, should be viewed in the framework of the clinical decision-making process since embryo transfer strategy is not chosen randomly but rather depends on the quality of the embryo, prognosis of the patient, and the judgment of the clinician. Through the identified association, the underlying selection trends in clinical practice can be to a certain extent represented.

The lack of statistically significant difference between fresh and frozen embryo transfer cycles suggest that the nature of endometrial environment is not a determining factor on clinical pregnancy outcomes in this group of data. It is particularly true in the context of the contemporary ART practice whereby the practice of frozen embryo transfer (FET) has gained popularity due to the advent of the cryopreservation process and the adoption of freeze-all methodologies. The fact that fresh and frozen cycles have the same rate of pregnancy indicates that the two procedures are clinically the same and that the choice of either of the two approaches can be more depending on individualized factors of treatment rather than necessarily because of the dissimilarity in the success rates.

The results that were of interest on sperm selection method should be taken with care. Though univariate analysis indicated that the double density gradient (DDG) method had a significant relationship with an increase in pregnancy rates, this could not be verified in multivariate analysis. This suggests that confounding variables or imbalance of the number of cases in groups may have caused the original significance particularly because the non-DDG cases are very small. Moreover, categorizing the alternative methods as unknown brings heterogeneity, which limits the possibility to make conclusive results on the independent impact of sperm preparation methods on ART outcomes.

The secondary outcome measure of live birth recorded low rate significantly and this was not consistent with the clinical pregnancy rate that was recorded. Such discrepancy is a great sign of either no follow-up or underreporting in the retrospective data compared to a true coverage of clinical outcomes. This implied that live birth could not be a significant outcome variable of an inferential nature. This highlights a major drawback of retrospective studies in reproductive medicine, in which long-term data need to be followed up, both fully and long-term, which might not be possible with regular clinical data.

Comparing the present study to the past research, the results obtained are widely in line with the literature available as well as there are some limitations of the dataset. The fact that fresh and frozen cycles show similar results is consistent with the data that suggest that no significant difference exists in the efficacy of fresh and frozen cycles in the existing ART practice (Wong et al., 2017; Cedars, 2016). The basic principles of implantation biology would be the significance of embryo transfer strategy as observed in the current study where the probability of success would be increased since there would be more embryos transferred (Denker, 1993). This lack of significant independent age effect may be due to the fact that the age interval in the study group is relatively narrow but it is a widely accepted fact that age is a very strong variable that has significant influence on reproductive outcome (Segal, 1974). Likewise, although endometrial factors have been proven to have an effect on implantation (Yuan et al., 2016), the lack of them in the final analytical model does not allow direct comparison. These sperm preparation results must be taken with caution and there are known variables in the lab such as the oxidative stress which interferes with the sperm functioning and fertility (Aitken & Curry, 2011). In a wider sense, the research can be added to the knowledge of the infertility trends and therapy outcomes among the clinical populations (Jabeen et al., 2022).

Admission of a number of limitations should be made. First, the retrospective type of design enables to control the data quality and completeness only up to some extent. Second, the huge number of cycles (1095) is reduced to 94 transferable embryos, which poses the threat of selection bias. Third, the last model lacked major biologically relevant variables such as the quality of the embryo and the endometrial thickness since the data available was not sufficient to make the model as comprehensive as possible. Fourth, the sample size (especially when analysing subgroups) was small, and may have diluted statistical power, and influenced the result of significant relationships. Lastly, live birth was undesirable, due to missing follow-up data.

Irrespective of these limitations, the study has significant clinical implications. The findings confirm the significance of embryo transfer strategy as a key variable in clinical pregnancy and the need to balance the success rates and risks (including multiple gestations) as high as possible. The ability of the results to be similar when fresh and frozen cycles are done, promotes flexibility of the treatment plans in the contemporary ART practice. The fact that the multivariate model was a mediocre predictor also highlights the need to come up with more extensive models that incorporate more biological and embryological variables. Future studies ought to be done on prospective data gathering, incorporation of elaborate embryo and endometrial values, and creation of powerful forecasting models to enhance clinical judgment in ART.

5. CONCLUSION

In this paper, predictors of clinical pregnancy in assisted reproductive technology (ART) cycles have been compared via a retrospective observation of embryo transfer cycles. The results indicate that the embryo transfer plan proves to be the most significant independent variable of clinical pregnancy and the double embryo transfer (DET) plan, offers a success rate in comparison to the single embryo transfer (SET). Conversely, the independent variables of the type of cycle (fresh and frozen) as well as sperm selection technique and the age of parents were not significant statistically in the data under analysis. The similar results of fresh and frozen embryo transfer cycles indicate that both methods are clinically feasible with the flexibility of treatment choice depending upon patient-specific factors. Whereas the results of the sperm preparation techniques were found to have a correlation in the univariate analysis, that was not the case in the adjusted analysis and it can be assumed that it was affected by the influence of confounding factors. The research has also revealed that the research experienced some major limitations such as; the retrospective nature of the research, the sample was incomplete due to the data filtering and the follow up of the live births was not done. These may have an impact on breadth and generalizability of interpretation. Overall, the findings reveal the importance of the procedural decision-making in ART, particularly embryo transfer strategy. The future studies should be based on prospective designs and include exhaustive biological and embryological variables in order to come up with stronger predictive models to enhance ART outcomes.

References

1. Aitken, R. J., & Curry, B. J. (2011). Redox regulation of human sperm function: from the physiological control of sperm capacitation to the etiology of infertility and DNA damage in the germ line. *Antioxidants & redox signaling*, *14*(3), 367-381.
2. Anjana, R. M., Elangovan, N., Pradeepa, R., Deepa, M., Unnikrishnan, R., & Mohan, V. (2023). Challenges in implementing nationwide epidemiological studies on metabolic non-communicable diseases in low-income and middle-income countries. *The Lancet Diabetes & Endocrinology*, *11*(12), 889-891.
3. Cedars, M. I. (2016). Fresh versus frozen: initial transfer or cumulative cycle results: how do we interpret results and design studies?. *Fertility and sterility*, *106*(2), 251-256.
4. Denker, H. W. (1993). Implantation: a cell biological paradox. *Journal of Experimental Zoology*, *266*(6), 541-558.
5. Jabeen, F., Khadija, S., & Daud, S. (2022). Prevalence of primary and secondary infertility. *Saudi Journal of Medicine*, *7*(1), 22-28.
6. Kuchakulla, M., Narasimman, M., Khodamoradi, K., Khosravizadeh, Z., & Ramasamy, R. (2021). How defective spermatogenesis affects sperm DNA integrity. *Andrologia*, *53*(1), e13615.
7. Lessey, B. A., & Young, S. L. (2019). What exactly is endometrial receptivity?. *Fertility and sterility*, *111*(4), 611-617.
8. Mascarenhas, M. N., Flaxman, S. R., Boerma, T., Vanderpoel, S., Mathers, C. D., & Stevens, G. A. (2013). Trends in primary and secondary infertility prevalence since 1990: a systematic analysis of demographic and reproductive health surveys. *The Lancet*, *381*, S90.
9. Pirlog, L. M., Pătrășcanu, A. A., Ona, M. D., Cătană, A., & Rotar, I. C. (2025). HOXA10 and HOXA11 in Human Endometrial Benign Disorders: Unraveling Molecular Pathways and Their Impact on Reproduction. *Biomolecules*, *15*(4), 563.
10. Raperport, C., Desai, J., Qureshi, D., Rustin, E., Balaji, A., Chronopoulou, E., ... & Bhide, P. (2024). The definition of unexplained infertility: A systematic review. *BJOG: An International Journal of Obstetrics & Gynaecology*, *131*(7), 880-897.
11. Segal, S. J. (1974). The physiology of human reproduction. *Scientific American*, *231*(3), 52-63.
12. Shakerian, B., Turkgeldi, E., Yildiz, S., Keles, I., & Ata, B. (2021). Endometrial thickness is not predictive for live birth after embryo transfer, even without a cutoff. *Fertility and Sterility*, *116*(1), 130-137.
13. Sun, H., Gong, T. T., Jiang, Y. T., Zhang, S., Zhao, Y. H., & Wu, Q. J. (2019). Global, regional, and national prevalence and disability-adjusted life-years for infertility in 195 countries and territories, 1990–2017: results from a global burden of disease study, 2017. *Aging (Albany NY)*, *11*(23), 10952.
14. Takhar, J., & Rika Houston, H. (2021). Forty years of assisted reproductive technologies (ARTs): the evolution of a marketplace icon. *Consumption Markets & Culture*, *24*(5), 468-478.
15. Wong, K. M., van Wely, M., Mol, F., Repping, S., & Mastenbroek, S. (2017). Fresh versus frozen embryo transfers in assisted reproduction. *Cochrane Database of Systematic Reviews*, (3).
16. Yuan, X., Saravelos, S. H., Wang, Q., Xu, Y., Li, T. C., & Zhou, C. (2016). Endometrial thickness as a predictor of pregnancy outcomes in 10787 fresh IVF–ICSI cycles. *Reproductive biomedicine online*, *33*(2), 197-205.
17. Zaat, T., Zagers, M., Mol, F., Goddijn, M., van Wely, M., & Mastenbroek, S. (2021). Fresh versus frozen embryo transfers in assisted reproduction. *Cochrane Database of Systematic Reviews*, (2).