A Review on The Role of Machine Learning Models in predicting In-Vitro Fertilization/Assisted Reproductive Technology Success

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Abstract: The aim of this paper is to provide a review of how machine learning models help to predict the success of pregnancy achieved with Assisted reproductive Techniques. Infertility is a serious concern nowadays. Due to social pressure, environment pollution, changes in lifestyle, many couples suffer from infertility. This paper aims at providing a review of problems faced by women who are undergoing IVF or ART to achieve pregnancy and how machine learning and Artificial Intelligence comes in support for women by providing effective models for predicting their pregnancies.

Keywords: IVF, IUI, ART, infertility, Machine Learning, fertility, Mental Health, Obesity, PCOS, PCOD

Introduction

Assisted Reproductive Technology is a general Term for representing fertility treatments that involves handling eggs, embryos to achieve successful conception. IVF is one of the ART that helps couple to achieve successful conception. Infertility nowadays is a serious concern that needs an important attention. Due to change in lifestyle, stress levels, work pressure, environment pollution, the cases of infertility are increasing. IVF or ART methods require a lot of patience, cost, faith to reach to its successful conception levels. There rises a need of some models or techniques which could predict or guide the aspiring couples to go for ART methods. Artificial Intelligence, as we all know has become a part of everybody life whether one needs to chat, need suggestions, in customer care, business Intelligence. There is a need for certain Machine Learning Models that could predict the success of ART methods as this process are costly. ART includes fertility treatments where in females, ovaries are stimulated to produce more eggs, medicines are provided to enhance the quality of eggs produced by ovaries and in males' sperm quality is enhanced by medicines and by adopting good living lifestyle. IVF is one of the ART technologies which is done in three steps: egg retrieval, fertilization, and embryo transfer. There are various factors on which IVF is performed. Since this process involve major health turmoil and cost, machine learning models can be used to predict whether any couple should go through this process in which hormones are misbalanced, mood swings are on and financially a couple is drained. There are various factors that predict successful pregnancy one is Are the periods cycle regular? Are you adopting proper lifestyle that involves proper intake of fibers, antioxidants? another is are you taking a lot of stress? One major problem in females found is PCOS i.e. polycystic ovarian syndrome in which is a type of hormone change in females that causes irregular periods, excessive hair growth and weight gain. PCOS can lead to various complications like gestational diabetes, miscarriage, and endometrial cancer. Another factor is embryo survival, egg quality, egg retrieval procedure which future produce major complications like changes in vaginal discharge, weight gain, risk of infection. A typical IVF involves a lot of medicines and injections. Moreover, it's not just one IVF, if successful conception is not received, same process is repeated to get the successful conception. This Process is quite stressful for couples. Worldwide, Infertility is estimated to affect about 8- 12%of couples in reproductive age [1]. Studies have found that patients with endometriosis have lower clinical pregnancy rate poorer ovarian response, lower egg retrieval rate. A Successful pregnancy rate is affected with maternal age, obesity, and stress. Another approach of ART is IUI, which is Intrauterine Insemination, which is also a simple fertility treatment in which sperm is directly placed into the uterus to improve the chances of pregnancy. IUI is much simpler process than IVF.

Usually, IUI is the first line treatment offered by Gynecologist as it is much simpler and easy option. Once IUI is unsuccessful, IVF is suggested. Initially complete demography of female is studied to understand the female body. This study includes BMI (Body Mass Index), weight, Height, daily lifestyle, diet intake, exercise, intercourse frequency, medicine intakes, Blood pressure, hormonal issues like excessive weight gain or weight loss, excessive facial hair growth, dependency on fast foods, exposure to heat, etc. Demography of Male is also taken as sperm quality also plays an important role but paper focusses on female health. The next step for female is to provide her supplements depending upon her reports and suggesting better life style including injections and medicines for IVF. Then comes the step of improving egg quality which is done through proper diet and injections. Then comes the step of fertilization, where the collected eggs which are frozen are fertilized with sperm of man. Last step is embryo transfer, in which successful embryos are planted into uterus on day 3 or 4 of egg retrieval. Sometimes embryos are transferred after reaching blastocysts stage on day 5,6 or 7. General Terms used in the paper are explained below:

a) IVF: In Vitro Fertilization is method of Assisted Reproductive Technology that involves retrieval of

eggs from women, fertilizing with sperm in lab and then transferring the fertilized embryo in uterus. In this process, vaccines and medicines are given to women for successful conception.

b) IUI: is Intra Uterine Insemination, where sperm is transferred directly in to uterus. This process is simple and less complex compared to any other ART techniques.

c) ICSI: is Intracytoplasmic Sperm Injection in which single sperm is injected into matured egg. This is usually performed where sperm count is low.

d) PCOD: Polycystic Ovarian Disease is a hormonal disorder in females that cause ovaries to enlarge with cysts on outer edges. This leads to delay in menstruation or missed periods in women which may lead to weight gain, facial hair growth.

e) PCOS: Polycystic Ovary Syndrome is a mix of genetic as well as environmental factors. This also involves delay in periods or missed periods.

f) Obesity: is also a problem in which body fat is increased due to PCOD/PCOS which may lead to heart as well as fertility problems in women.

g) Fertility: is the ability of a human in which she can give life to new human. This takes into good health, fit body, good food
,healthy lifestyle and healthy periods cycle.

h) Infertility: is the situation in which couple even after unprotected sex does not able to conceive either due to low sperm count or PCOD or hormonal Imbalance.

Role of Machine Learning Models or Ai in IVF or Assisted Reproductive

Methods

Artificial Intelligence is almost in all fields whether it is finance, health care, business Intelligence, Road Safety, cyber security, and a lot more. AI is integrated in all fields to improve the quality of one's life. When it comes to IVF, it brings along a lot of pain, financial expenses, changes in health and most important the outcome. Not everyone can afford the assisted reproductive methods to achieve a successful conception but everyone has a desire for a child. Here comes the role of AI, as AI can suggest you better products, better services, a solution to your everyday problems in the same manner it can offer a solution to the couples whether one should opt for IVF or not. We can make a Machine learning model that can take certain parameters and predict whether you should opt for IVF or if you change your diet or adopt healthy lifestyle you need not to go for IVF, you can have a natural conception. AI can save one from spending a lot on ART methods and pain. The Flowchart below gives a complete overview of role of AI in ART Procedures.

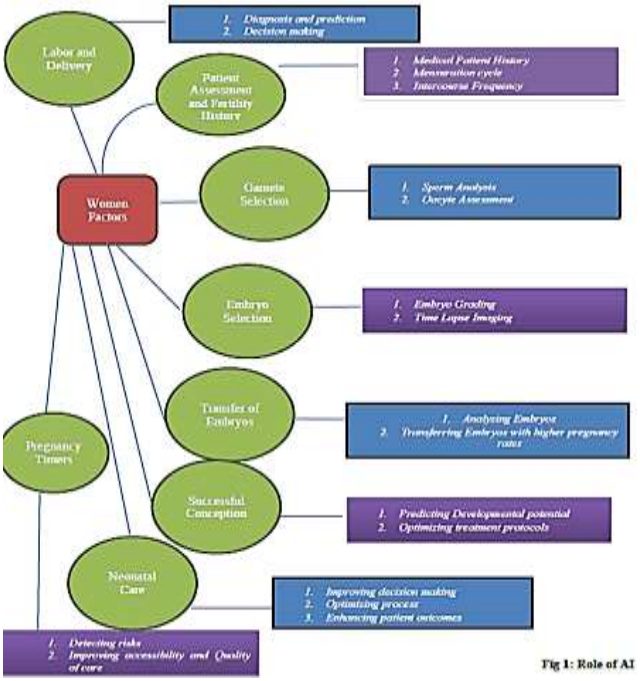

Fig 1: Role of AI in ART

Review of Literature

The Paper provides a review of 19 Research papers that demonstrates the Role of AI/ML in ART. [1] Paper studies the impact of endometriosis on pregnancy results of women who are undergoing treatments like IVF. The Study aims to improve the live birth rates. Overall, 330 patients with endometriosis are considered for study. The patients are divided in to three groups, first is the one who requires no treatments, second is the one that are treated on time and last are the one that took late treatments. Results in three groups came out to be 43.6% in the ones that took treatment at right time, that took late treatments the result were 46.3% and the ones that do not take any treatment comes out to be 27.7%. The fertilization rates were also higher in treated groups i.e. 64.40% (treated on time), 60.27% that are took late treatments and 46.24% in untreated groups. Hormonal Imbalance may affect embryo quality, oocytes development. Paper concluded with the fact that endometriosis may affect the process of IVF/IUI. If treated on time, the quality of embryos is improved.[2] Paper studies the risk of pregnancy complications like preeclampsia, previa, abruption, postpartum hemorrhage. Machine Learning Algorithms used are Logistic regression, Decision Tree, Naïve Bayes, SVM , random Forest and Gradient Boosting. Two models for each cycle is made: 1) Before Treatment; in which demographics and medical treatment history is analyzed and collected, 2) After Treatment Model in which ART treatment characteristics are taken in to consideration. Took all time mothers who gave birth up to three ART cycles between 2008 and 2016. Major predictors used are age, BMI, Country of birth, ART cycle details like embryo transfer type, number of eggs retrieved, etc. Some pregnancy predictors like smoking, alcohol, etc. The result comes out to be 66% in preeclampsia,

66% in placental complications and 60% in postpartum hemorrhage. The Limitation is prediction accuracy, lack of real time pregnancy data where the strengths specified are: Robust validation with ML algorithms and availability of clinical data. Paper concluded with the fact dynamic factors during pregnancy can predict the complication better as machine learning algorithms either use pre or post ART data. [3] Author uses Machine Learning to predict the IVF success rates with the aim to reduce mental, physical and financial burden on couples aiming for conception. Total of 333 records are used with parameters like FSH levels, AFC. AdaBoost and Random Forest models are used where AdaBoost gave accuracy of 99.6% and Random Forest gave 97.5%. The study proves that ML can be used effectively to predict the IVF success and to give personalized treatment to patients. Future scope includes integrating embryo images with lifestyle to get better prediction. [4] Author used Machine learning to predict female infertility. Data is collected from Peshawar Hospital and data are analyzed using Logistic Regression, SVM, Random Forest, where in conclusion random forest gave accuracy of 93%. The study aims to provide relief to infertile women by providing them a way to predict their IVF success rates. The data is preprocessed by removing duplicate and missing values. 80% data is used for training and 20 % data is used for testing sets. Machine Learning Models used are: Random Forest, Logistic Regression, Support Vector Machine, and Naïve Bayes. Paper concluded with random forest being the best model and a strong performance by Logistic Regression as well. In future Prospects paper looks in to involving deep learning methods with machine learning models and focus on involving lifestyle and psychological factors to get better prediction. [5] Paper aims at using Artificial Intelligence to select embryos in process of IVF to improve the live birth rates or chances of conception. Total of 19201 static embryo images from 8271 patients are taken ,418 time lapse videos are taken and clinical data from China hospital is taken to analyze. Total of four AI models are created: Embryo grading, Blastocyst prediction, euploid detection and live birth prediction. Major inputs to the AI models are: Embryo grading, blastocyst assessment, chromosomal abnormalities and live birth prediction. Paper concluded with the fact that AI predicts better than the embryologist. It proves that AI can better predict the live birth outcome by selecting better embryos to be transferred in IVF process. AI is more explainable and superior tool as compared to embryologists.[6] Author aims at analyzing the existing IVF prediction models. Author used 26832 IVF cycles of Chinese medical Center and came out with conclusion that existing models need to change as per the needs. External models tested like Luke model, Dhillon Model and center specific model built using XGBoost, Lasso Regression and GLM. Author focused on improving the efficiency of these models to give more accurate prediction and better personalized experience. General models work with underestimate outcomes, center specific models provides better predictions hence better accuracy. [7] Paper aims at using Artificial Intelligence especially Deep Learning to improve the selection of embryo in IVF process to improve success rates. Author developed DeepEmbryo to select better embryos and improve the live birth rates. CNN architectures are also trained using transfer learning on images. The best CNN achieved accuracy of 75%. 252 embryos from IVF cases from IRAN is taken , pregnancy is predicted with HCG test. On the conclusion , Deepembryo turns out to be a promising solution. Three time point image analysis is much better as compared to single point analysis, AI is more accurate and reliable.[8] Paper aims to analyze how personalized tool affects the IVF process using AI. For this data of 24000 patients is collected from total seven centers from US and Canada between 2016 and 2022.Retrospective Analysis is done from 7 fertility centers. Univfy model is used for estimating IVF live birth predictability. Univfy has higher conversion IVF success rates . Paper state that at age 34, Direct IVF rate is 34% and at age 40, Direct IVF rate is 37%. Univfy is AI model which is patient centric, scalable, cost efficient, and has a real world adoption. Author concluded with the fact that if personalized treatments are provided they give better picture to the couples and a better understanding of IVF process and better results as compared to ones who do not go through the personalized ones. AI/ ML efficiency should be used by the clinicians to get better results. Centre specific IVF counselling may result in better take up of ART methods as it improves efficiency, access and personalization in fertility centers.[9]Author has an objective of applying AI at ovarian simulation step of IVF. Generally, SVM, Random Forest and Gradient Boosting are used for prediction. Author concluded with the fact that ovarian stimulation is the critical step of IVF but dataset is limited, real world testing is also limited due to which there exist problems in analyzing the data. More sharing of data is needed to predict accurate results.[10] Paper studies the role of AI and ML in sperm analysis and reasons for male infertility. Areas like sperm Concentration and count, sperm motility, Sperm morphology, DNA Integrity, Testicular sperm extraction are studied. Total 306 articles are studied. Paper concluded with the point that AI can handle sperm, infertility in men but there are some challenges like data standardization, clinical data validation and ethical concerns.[11]Author introduced multi modal contrastive learning on images and videos of embryos thereby challenging the traditional system of embryo selection. The built system produces three clinical tasks like Morphological assessment, euploid prediction and live birth outcomes. Author concluded with the fact that built system is less costly, may standardize the process of embryo selection thus improving the live birth rate in IVF.[12]Paper evaluates ML efficiency i.e. why ML models produce inconsistent results when predicting IVF success rates. Challenges faced by ML in IVF process are: Inconsistent performance, unavailability of features during prediction,

lack of validation and clinical data. Two solutions are proposed : stage by stage modelling and subgroup modelling using FMLR. The study concluded with the fact that clinically aligned ML models can predict better IVF success rates as they will be realistic predictors.[13]Paper presents ML model at predicting outcomes in ICSI method of ART. 345 couples undergoing ICSI are analyzed. Causes of sperm retrieval are also specified like: OA, ED, TED. Six ML models are used: KNN, SVM, RF, Catboost, GBDT, XGBoost. Out of all XGBoost is the best with an accuracy of 79.71%.Paper concluded with the fact that this is the first model specifically for analyzing male fertility. [14]Author built an ML model that predicts IVF birth rate and provides optional embryo transfer strategies to ensure whether pregnancy will result in success or not. Data of 1405 patients are taken. ML models like SVM and ANN are used , as a result SVM is better than ANN in terms of accuracy. Paper concluded with SVM is better as it offers better LBO prediction, it aims to provide personalized IVF treatments that will definitely improve IVF success rates.[15] The study comapres four deep learning models. About 1020 images are taken from Vietnam. Efficient Bo has highest accuracy of 90% Where VGG-19 has good accuracy , mobile net has an accuracy of 87% and ResNet50 has weak performance. Paper concluded with the fact that Efficient Net -B0 is best for small datasets.[16] paper aims to study factors that affect live birth and process of IVF in PCOS patients. About 1062 IVF patients with PCOD are studied, where 466 are live births. Total of 7 Ml models are tested and compared , Dt, KNN, NBM, RF, SVM, LightGBM, XGBoost. XG boost is the best performer among all with accuracy of 75.2%. Blastocyst transfer, fresh embryo transfer in PCOS patients can result in successful pregnancy. Overall XGBoost is best in patients diagnosed with PCOS with fresh embryo transfer can result in successful pregnancy.[17]Paper gives a review of male infertility in context of IVF. Role of IVF in male infertility, predicting outcomes in IVF and ICSI and role of AI in treatment decisions is studied.Major 14 studies are reviewed. ML models used are: SVM, RF, XGBoost, LR, Deep Neural Networks, Lasso and K means clustering. To conclude, AI is better than traditional methods, Predictive models improve the IVF planning.[18] paper gives a review of role of AI , Deep Learning and Machine Learning in various steps of IVF. Main focus is on how AI improves personalized treatment, process of IVF, IVF success rates. Application of AI in IVF involves: ovarian stimulation, gamete selection, embryo selection, Lab control, scheduling. Paper concludes with the fact that AI improves precision, personalization, enhances the real time interventions. [19] Paper gives a review of 64 studies, explores how AI and Ml are helping in the field of Obstetrics and midwifery Main focus is on the role of AI and ML in reproductive and maternal care settings. Author focuses on Embryo selection, problems faced during pregnancy that involves gestational diabetes, preeclampsia; maternal health, monitoring during pregnancy of fetus, labor pains and delivery; neonatal outcomes. Paper gives strong facts on how AL and ML have their roles right from start of IVF process Through Pregnancy through labor and lastly neonatal care. The Review is summarized in Tabular form as:

#	Model& Performance	Important Features	Used features	Objective	Results
[1]	Comparison methods	Clinical pregnancy rate, early abortion rate, live birth rate, oocyte retrieval, AMH,AFC	Clinical data, oocyte retrieval	To study the effect of Endometriosis on the pregnancy results with implantation failure in IVF cycles	Endometriosis has negative effect on IVF. It is important for endometriosis patients to seek medical help to achieve a good prognosis
[2]	Cross Validation, Logistic Regression, Decision Tree, SVM, RF	Treatment Year, Age, Partner Age, Highest Education, BMI, Medical History	Age, BMI, Medical History	To Use Machine Learning methods to develop prediction models of pregnancy complications in women who conceived with ART	Author states that combined use of demographics, medical history and ART treatment information was not enough to predict pregnancy complications
[3]	RF, NB, LR, DT, AdaBoost and K nearest Algorithm	Age, AFC, oocytes, Embryos, DailyGn	DailyGn	To Predict the success rate of In-Vitro Fertilization	If age>36, there is negative propensity of clinical pregnancy and if age>40, the probability of clinical pregnancy dramatically declines. The propensity of clinical pregnancy is positively correlated to number of embryos transferred in the IVF cycle
[4]	Logistic Regression, Naïve bayes, SVM and Random Forest	Ovulation disorder, obstructed fallopian tubes, ovulation irregularities	Infertility Prediction	To use advanced Machine Learning techniques to present a novel method for predicting female infertility	Random forest is used to predict infertility in women. The suggested method can be used for individual treatment solutions
[5]	CNN	Embryo Images and Medical Records, Age, FSH,AMH	Live Birth prediction	An automated system that can evaluate heterogenous embryo data to predict the final outcomes of livebirths.	A general AI platform is built for embryo evaluation and live birth occurrence
[6]	XGBoost, Lasso Model, Generalized Linear Model	Age, BMI, Height, Previous Birth, Miscarriage	AMH, AFC and body weight	To check the performance of different pretreatment prediction models for IVF	Study suggested that models derived from a national registry like HFEA could also provide a meaningful predictors for patients from a different region with modest discriminatory power
[7]	CNN architectures (AlexNet, ResNet18, ResNet34, Inception V3, and DenseNet121)	Embryo images	Embryo images	To use to predict pregnancy success using embryo images ,studying current IVF process with embryo images and comparing results of AI based methods and embryologists experts in predicting pregnancies	Five well known CNN architectures are used , Deep Embryos using three embryo images predict better results as compared with one using one final image.

[8]	18ID, 360 Days and over	First IUI, IVF, BMI, FSH, AFC, AMH	AMH	The study investigates the IVF utilization rates associated with machine learning and center specific prognostic reports	Usage of ML/CS-based Prognostic report was associated with Increased IVF conversion among new fertility patients.
[9]	Support Vector Machine	Gonadotropin-releasing hormone, HCG	GnRH	The paper objective is to examine the literature to explore the AI models used for predicting Ovarian Stimulation Outcomes in the context of IVF	Around 1348 articles are reviewed, out of which 30 are met with the predefined criteria. The main predicted outcome is based on number of oocytes retrieved. The reviewed literature provides various features ranging between 2 to 28054 features.
[10]	SVR, CNN, ANN SVM, RNN, THMA, MLP	Concentration, sperm count, motility, morphology, DNA Integrity	Live birth success rate.	The author Reviews the current updates on semen analysis	The author concludes with the fact if the semens are chosen by andrologist and embryologists by using AI then this may result in more success rate.
[10]	SVR, CNN, ANN SVM, RNN, THMA, MLP	Concentration, sperm count, motility, morphology, DNA Integrity	Live birth success rate.	The author Reviews the current updates on semen analysis	The author concludes with the fact if the semens are chosen by andrologist and embryologists by using AI then this may result in more success rate.
[11]	SSL VTCK FRAMEWORK	Embryo Images, videos, maternal metadata and clinical outcomes	Embryo images, clinical data	The AI Framework is proposed that evaluates the embryo images and videos while performing IVF process	AI framework is trained and a gradient based, attention based and shapely based method is used for interpretation of images. To evaluate the performance of the framework, author applied mean absolute error, etc.
[12]	Logistic, Random Forest, SVM, Neural Network, XGboost	HCG	HCG	Comprehensive review of research till date and developed two modelling approaches phase – by – phase modeling and FMLR modeling	The author suggested a machine pipeline that involves phase by phase modelling that is for clinicians to analyses the potential at each step of IVF and second is FMLR modelling that helps clinicians discern hidden patterns in heterogeneous data.
[13]	KNN , SVM, RF, CatBoost, XGBoost, Gradient Boosting Decision Tree	Age, BMI, tobacco use, FSH, TV, TT	BMI, Age, FSH	Author aims to develop a robust Machine Learning Model for predicting Clinical Pregnancy using Shapley Additive Explanation.	The XGBoost predicts clinical pregnancies of different etiologies with high accuracy, reliability and robustness.
[14]	ANN, SVM	BMI, Infertility Type, Infertility duration, Infertility cause	HCG, embryo transfer strategy, embryo images	The Study aims to build classification models for predicting live birth with ML	Predicted model can assist in providing scientific assistance to clinicians for customizing the IVF treatment strategy.
[15]	VGG-19, EfficientNet, MobileNet, ResNet	Embryo Images	Embryo Images	This paper provides a comprehensive analysis of the application of deep learning models for embryo quality assessment.	EfficientNet promise in grading accuracy with 90% accuracy. Factors like egg quality, fertility, uterine receptivity should be included in IVF, chances of successful conception.
[16]	XGBoost	Maternal Age,BMI, Infertility Duration,embryo type,serum testosterone levels, progesterone levels	BMI, progesterone levels	This paper aims at considering that segment of patients who are suffering from PCOS ,by predicting live births in these patients.	Among 7 ML models , XGBoost is most effective. Shapely Additive Explanations(SHAP) analysis also states clinical predictors of live birth includes embryo type, embryo transfer count, maternal age , infertility

[17]	SVM, MLP, RF, GBT, Deep Learning Models, Logistic Regression, K Means Clustering	Sperm morphology, sperm motility, sperm quality, sperm pH levels	Sperm ph Levels, IVF outcome prediction, sperm concentration	The paper aims to assess AI efficiency, identification of sperm characteristics, provide personalized experience, limitations of traditional methods	Paper is concluded with the fact that there exists strong relation between sperm quality and IVF success rate.AI models have capability to provide personalized experience to patients. AI has the potential to make IVF a success.
[18]	ML Models, Deep Learning Models	Age, BMI Index, AMH levels, Patient Characteristics, AFC	AFC, AMH	Paper explores current developments using AI , ML and DL in IVF. Aims to provide benefits of these technologies . Provides Future scope of AI , ML , DL in IVF	IF AI is used with IVF , it can truly improve the live birth rates. AI has the potential to provide personalized experience and better care to the patients.
[19]	XGBoost, logistic regression (LR), random forest (RF), SVM, LightGBM, multilayer perceptron (MLP), Random Forest, Unsupervised Learning, STORK-A	Embryo Images, Aneuploidy status, complex aneuploidy, single aneuploidy, embryo quality, and morphology.	Aneuploidy status, complex aneuploidy, single aneuploidy, embryo quality, and morphology.	Paper aims to provide current advancement in IVF through AI models	AI and ML Models hold the potential to transform obstetric and midwifery care. The widespread adoption is needed to improve clinical results.

All Major area is covered in the review specifying the role of AI, ML models in field of ART methods. Figure 2 specifies the Number of Publications in Role of IVF especially specifying Women's. (year 2020-2025).

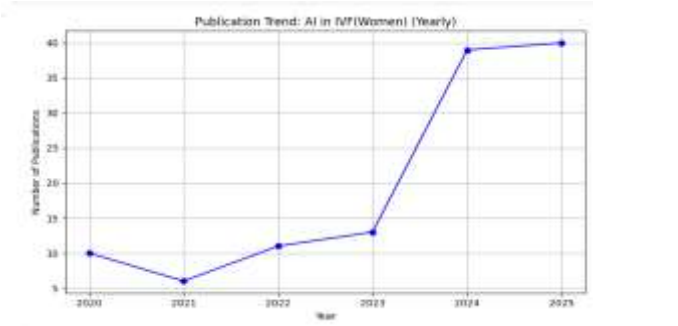

Fig2: Publication Trend in AI in IVF(Women)

Conclusion

The paper presented above gives much understanding to role of AI in determining/ predicting the success of pregnancy achieved through ART methods like IVF, along with-it paper gives a review of research that involves the development of AI Frameworks and involvement of Deep Learning to predict the successful pregnancies. Paper also states and reviews various parameters that are to considered for successful conception through ART Technologies. Review gives a brief understanding of parameters on which ML models can be built. Effective Collaboratrion of AI, ML and Deep Learning Models can enhance clinical results , can improve personalized patient care that gives clear understanding of the procedures . It can prepare patients for the procedure by learning the pros and cons of procedures and can help them to focus on better health whereas fertility clinics if incorporate AI models can get more healthy live births leading to more successful IVF leading to helping couples providing them satisfaction and their bundle of joys i.e. successful conceptions.

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