AN ASSESSMENT MODEL FOR THE PREDICTION AND ANALYSIS OF IVF USING APPLICATION OF MACHINE LEARNING AND ARTIFICIAL INTELLIGENCE TECHNIQUES

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Abstract

Infertility is the amalgam of aspects that put a stop to pregnancy that is, it is a condition in which you cannot get pregnant after one year of trying to conceive. It involves a lot of care and expertise while choosing the best fetus that leads to a successful pregnancy. Assistive reproductive technology (ART) helps to solve this problem. In vitro fertilization (IVF) is one of the most popular forms of ART. Artificial intelligence plays a digital revolution and numerous advances in the field of reproductive medicine and eventually provides huge benefits to infertile victims. The main purpose of this article is to focus on methods that can predict pregnancy with high accuracy without human intervention. It provides fruitful lessons learned using machine learning methods. This makes it easier for the physicians to understand the behavior of the treatment. Blastocyst images are being distributed to detect and predict the best embryo possible for a successful pregnancy. This pioneer service gives an idea of how the ministry can benefit the next generation.

Keywords: Embryo Grading, Blastocyst, Embryo Selection, IVF, Artificial Intelligence, Machine Learning Techniques, Deep Learning, Neural Networks, ART

I INTRODUCTION

IVF, or in vitro fertilisation, is used in assistive reproduction for the past years. Following that, IVF has numerous important advancements, including the transition to single embryo transfers and extended embryo culture at physiological oxygen levels. IVF patients may suffer from miscarriages. However, many infertile patients find that the road to motherhood through IVF is a time-consuming, emotionally taxing, and financially difficult journey. Research is primarily focused on finding ways to increase the existing 30% success rate of IVF [1]. Other areas that could use improvement include patient-specific treatment plans, better eggs, embryo selection, enhanced endometrial receptivity, and early pregnancy care techniques.

The entire IVF journey starts with the embryologist playing an important role in the pre-diagnosis stages of a couple receiving IVF treatment by setting up reproductive assistance and clinical support provided by fertility consultants. The second stage involves the culturing of sperm, eggs, and embryos, which are inspected under medical conditions. The main purpose of this stage is to understand, plan, and manage the defects that is investigated prior to the next fertilization. Next, embryologists who examine the embryo morphology perform procedures such as embryo grading, embryo freezing, and selecting the best embryos for implantation. A cycle is the processing of an embryo for fertilization. Embryologists then freeze the embryos until successful outcomes are obtained. An IVF procedure cannot be performed if implantation failure occurs even after repeated embryo transfers. Manual embryo grading is a mind-numbing and time-consuming job. It would be easier if a machine can perform this process without human intervention. With this in mind, using AI and deep learning techniques, it is very helpful in finding the best embryo that can be induced.

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Three steps are used to achieve IVF using AI and ML techniques:

- Build a model to know the success rate of IVF and whether you need to continue it.
- Predict how many IVF cycles will be successful;
- Selection of the best quality fetus increases the chances of pregnancy even before IVF treatment.

This work helps to learn about various Machine Learning and AI techniques and their handouts for infertility treatment. For this survey, the data was collected from various search engines and previous works done by researchers and experts.

II LITERATURE SURVEY

Behnaz Raef and Riza Ferdousi (2019) [2] reviewed Machine Learning approaches in Assisted Reproductive Technologies. Their aim is to review machine learning methods for the production of ART. Hassan, M. R et al (2018) [3] proposed a hill climbing feature selection algorithm combined with Machine Learning methods for analysis and prediction of IVF with greater accuracy. They extracted seventeen features from Data Mining algorithms and selected the set of features to improve the prediction accuracy. Another work has been proposed by the researchers Tadepalli, S. K., & Lakshmi, P. V. (2022) to analyze and predict the IVF pregnancy using Machine Learning algorithms [4].

III THEORETICAL BACKGROUND

According to statistical surveys, more than 10% of the world's population faces infertility (Haimovici, 2018) [5]. Infertility is the inability to get pregnant one year after unprotected sexual intercourse due to many combinations of factors. Appropriate assisted reproductive technology is applied to a successful pregnancy when determining aspects of a couple's infertility. Embryo and oocyte quality are predicted using artificial intelligence methods. In vitro fertilization is a type of art that preserves male sperm and female eggs in a medical condition and inserts them into the female uterus. Reasons for infertility include obstruction of the fallopian tubes, diabetes, old age, smoking, alcohol intake, irregular menstruation, hormonal imbalance, decreased sperm count, and certain genetic disorders.

ART uses many varieties of approaches to deal with various problems:

1. In vitro Fertilization (IVF): It is the most successful ART method.
2. Intrauterine Insemination (IUI): Eggs are fertilized inside the uterus of a woman. When compared to IVF, the success rate is low. But the price is reasonable.
3. Intracytoplasmic Sperm Injection (ICSI): This procedure uses a woman's own eggs as a source of sperm, which is then injected into one of the eggs. When the egg fertilizes, the fertilized egg is then transferred to the woman's uterus. The best solution for sperm-related problems is this.
4. Intrafallopian Transfer: Unlike the previous techniques, the women's fallopian tubes are used to fertilize the eggs. This procedure, which can be completed in two visits, is the best option for women who have fallopian tube difficulties. Two procedures available here are:

a. Gamete Intrafallopian Transfer (GIT)
b. Zygote Intrafallopian Transfer (ZIT);

5. Surrogacy;
6. Test tube baby.

Aneuploidy is the measurement of chromosomes that results in infertility. When the number of chromosomes is different, infertility results, and 60% of women experience miscarriages [6]. Therefore, a technique known as Comprehensive Chromosome Screening (CSS) focuses primarily on chromosome abnormalities. It summarizes the likely benefits of getting pregnant. The parameters that are needed for the blastocyst evaluation mainly rely on the chromosomes that are mapped with blastocyst morphology.

It creates the possibility of implantation, which leads to a healthy pregnancy.

The couple, struggling with infertility, must first go through some initial medical procedures before implementing assistive methods. This entails hormone therapy along with medicines to clean the fallopian tubes. ART procedures are suggested when these treatments are unsuccessful. IVF, however, is the most effective and adaptable technique. Data mining is used during ART operations to ensure success. An approach, information fuzzy network and association rule mining, was tested in 2005 with an eye on a real significant characteristic that greatly contributes to the target attributes [6].

Vitro Testing is defined as 'in the glass,' or when different tissues, organs, or cells are tested apart from organic materials. However, this is unaffordable and it isn't known how many cycles are needed to predict the pregnancy. IVF includes retrieving a large number of mature eggs, fertilizing them under clinical circumstances, and implanting the fertilized eggs into the uterus after some days. But the most crucial and important IVF task is to transfer the best embryo. This can be accomplished using the initial cycle's method and transferring one or two embryos.

The embryo begins as a single cell and gradually divides into more cells. An oocyte refers to an ovarian cell that has the potential to go through meiosis and develop into an ovum. An ovum is the mammals' mature female gamete, which is what fertilizes to form the fetus. Before implanting a fertilized embryo into a woman's womb, embryos undergo the same development phases as a typical viable embryo. "Zygote" refers to the first two days of fertilization. The embryo is referred to as a multicell embryo on day 3 and a blastocyst on day 5. In order to boost the success rate of IVF, other techniques are used in addition to creating an embryo. This comprises:

- Ovarian Hyperstimulation: Inducing multiple follicles during ovulation
- Natural IVF: Without using any drugs for Ovarian Stimulation.
- Oocyte maturation
- Eggs retrieval
- Embryo culture
- Embryo grading
- Embryo selection
- Embryo transfer

IV OBJECTIVES

The main goal of the embryonic examination was to sort and rank the group of embryos in a patient's group according to how easily they could be implanted. Given that the value of the collection is linked to the implantation potential, the actual predictions of the AI model for each embryo are of limited value in this paper. In clinical practice, a pure-level model may assist in filtering the cluster's embryos, but it might not be useful in identifying which embryos are suitable for transplantation or cryopreservation. However, more recent methods, aim to make predictions that precisely mirror the implantation of implants, giving embryo testing a second objective in the form of potential measurements.

Thus, determining which embryos should be prioritised for transplantation and which should be preserved in cryopreservation may be made easier with the help of a predictable rate of implantation for each embryo, which may be paired with patient characteristics. Therefore, a foreseeable prognosis can also make patient communication easier and better. In this study, we discriminate between two goals and group them into standard and prediction categories, respectively. These two goals have a direct connection with model discrimination and models with various performance metrics. Therefore, one must be aware of the goals that have been formed and examined while looking at early AI models. In a similar vein, it's crucial to

consider how the test reflects the model's intended application. For example, a model that is only tested on transferred embryos apparently takes the preliminary selection made by embryologist experts of embryonic sub-cohorts and is therefore intended to be used as a supplement to man-made experiments. A fully automated model with the intended use of analysing all embryos in the embryo, on the other hand, needs to be tested in all embryos.

The aim is to perform a series of analyses that define an artificial intelligence (AI) model for measuring the stage of blastocyst embryos. The primary objective was to evaluate the benefit of a clinical pregnancy prediction model, while the secondary objective was to identify potential limitations in clinical practice.

V METHODOLOGY

Different methods of Machine Learning can be applied in IVF.

1) Supervised Learning

a) Decision Trees

Both classification and regression issues can be resolved using the decision tree. However, the classification issues are the most frequently encountered. It is a tree-structured classifier, where each leaf node symbolises the result, the branches symbolise the decision-making processes, and the interior node symbolises the features of the dataset, respectively, the leaf node and the decision node. Any choice is made using decision nodes, which have a number of branches, and leaf nodes, which are the output of the decisions but do not have further branches. The Iterative Dichotomiser (ID3), C4.5 (successor to ID3), Classification and Regression Trees (CART), and Chi-Square Automatic Iteration Detector (CHAID) are the best models to use when implementing decision trees.

ID3: Using this approach to create a decision tree is quite successful. Two prerequisites for the ID3 calculations are entropy and information gain:

The attribute with the biggest information benefit can be taken into account while creating a decision tree. A decision tree is built using the Gini index for binary attribute class labels. This approach is used by CART to build the tree. After the tree is built, its size should be the primary observation. Therefore, pre- or post-pruning is done to prevent the over-fitting idea.

The earlier study includes Passmore's [7] work on the C5.0 Decision Tree Inducer, which is utilized to pick the feature and has improved the performance in comparison to statistical models (Passmore, 2003). In order to improve the performance of the model, Srinivas Kilambi employed Principal Component Analysis (PCA) and logistic regression to choose the best feature. In order to forecast factors influencing pregnancy during IVF, Cai employed Multivariable Logistic regression and Bootstrapping [8]. Balogun et al., developed a classical model for predicting infertility in women using the Waikato Environment for Knowledge Analysis (WEKA-J48 model), which is evaluated by taking into account 14 different predictor attributes (Balogun, 2018). With the use of a genetic algorithm and decision tree, Milewska and Guh looked at a set of characteristics to predict pregnancy [9].

b) SVM Classifier

By utilizing hyperplanes to both the good and bad class labels, their classifier method predicts the class labels. $W.X + b = 0$, where 'W' stands for weight vector, 'b' stands for scalar value, and 'X' for the corresponding attribute value, is the equation for the hyperplane [10][11]. When compared to Naïve Bayes and SVM, a hybrid approach classification algorithm produced better results. Frequency-based encoding technique was suggested for the communication of categorical data and to enhance SVM performance in the classification of embryos. The task of factor identification

and label prediction in relation to IVF attributes is challenging. A method to utilize SVM to resolve diagnostic issue is suggested.

c) Naïve Bayes Classification

A probabilistic model is used by this programme. It examines each probability for each true and false instance, as well as the conditional probabilities of being true or false. Malathi used Hybrid models, and the results were very gratifying and more accurate than those of SVM and Naïve Bayes [12]. It's crucial to distinguish between embryos based on uterine implantation. The imbalance between true and false cases is handled by the Naïve Bayes Classifier. Güvenir tested with Successive estimates utilizing a ranking algorithm (SERA) to identify the characteristics most strongly influencing IVF therapy. The embryo selection process is crucial to the success of IVF. This is examined by employing a Naïve Bayes technique. By predicting infertility, Md Rafiul Hassan, Sadiq Al-Insaif, M. Imtiaz Hossain, and Joarder Kamruzzaman have investigated various classification algorithms that contribute to the prediction of IVF treatment and proposed a new feature selection technique called Hill climbing. This technique evaluates the critical attributes that can increase the classifier's effectiveness.

d) Ensemble Methods

The outcome of this technique can be based on the integration of numerous models into a single frame. The main techniques include bagging, ada-boosting, and random forest. Several authors have contributed their work on these practical strategies for this survey. The bootstrap aggregation approach is used to improve accuracy. The Naïve Bayes classifier has the highest accuracy after Cai distinguished between the bootstrap and the Naïve Bayes Classifier. An approach to assessing the implications of various data outcomes where the linked elements can be found for the fertility outcome is case-based reasoning [8].

2) Unsupervised Learning

In this approach, these are combined based on similarity rather than classification. Here, the class names are unidentified. Clustering focuses on centroid and sends random data points to the centroid that is closest to it. This technique is used to examine the intensity variables brought on by drug use in infertility.

a) Association Rule Mining

One method for observing the correlations, frequent patterns, and relevant measures of interest is based on rules and uses machine learning. Support and confidence are the two parameters that it uses to operate. A support factor defines how frequently a rule appears in a database, and confidence factor determines how many times a rule have been proven to be correct. The effectiveness of this approach has been demonstrated in the analysis of market basket, medical diagnosis, census data, DNA and protein sequences.

b) Performance evaluation of Models

Once the model is developed, the results can be determined using techniques that will be used to display the testing, such as precision, recall accuracy, sensitivity, and specificity, which can assess the model's functionality. Positive and negative tuples are the essential concepts that must be understood in order for this analysis to be successful. Positive tuples represent the YES conditions, and negative tuples represent the NO conditions for binary class labels. Precision and recall, the two other performance metrics related to classifications, are also relevant. The fraction of examples that are actually positive determines the precision or positive predictive value. Only the positive class of potentially positive will be predicted by an accurate model.

The following are the basic terms:

1. Precision=TP/(TP+FP)
2. Recall = TP/(TP+FN)
   - True Positive (TP): Correctly classified as the class of

interest

• True Negative (TN): Correctly classified as not the class of interest

- False Positive (FP): Incorrectly classified as the class of interest
- False Negative (FN): Incorrectly classified as not the class of interest

3. **Confusion Matrix:** It is a table that classifies predictions by whether they match the actual value. (Table 1);
4. **Accuracy:** The accuracy of a model can be defined based on the number of tuples that are correctly classified by the classifier:

   Accuracy = TP + TN /P+N
5. **Sensitivity:** The positive tuples that is correctly identified by the classifier:

   Sensitivity = TP/P
6. **Specificity:** The negative tuples that are correctly identified by the classifier:

   Specificity = TN/N

	Predicted Class 1	Predicted Class 2
Actual Class 1	TP	FN
Actual Class 2	FP	TN

Table 1: comparative analysis of various algorithms with accuracy

7. **Precision:** The percentage of total number of correctly classified positive tuples divided by the total number of predictive positive tuples:

Precision= TP/TP+FP

8. **Recall:** The percentage of total number of correctly classified positive tuples divided by the total number of positive tuples:

Receiver Operating Characteristic curves (ROC) are frequently used in order to evaluate and contrast two classification models to determine which one is best. A curve between True Positive Rate (TPR) and False Positive Rate (FPR) is drawn using this visualization tool (FPR). Here, specificity is defined by the FPR and sensitivity by the TPR

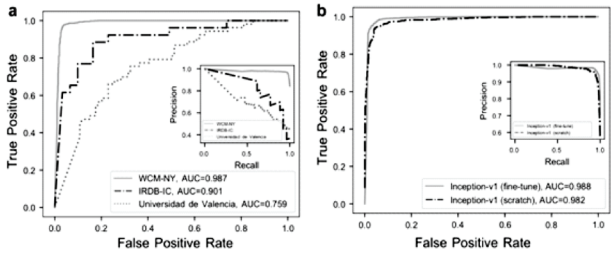

Figure 1: Deep neural network results: a) fine-tuning the parameters for all layer's results for three datasets. b) fine-tuning the parameters for all layers and training from scratch in good-quality and poor-quality embryo quality discrimination dataset.

VI. ARTIFICIAL INTELLIGENCE AND DEEP LEARNING TECHNIQUES-IMPACTS IN IVF

The success of IVF is largely judged by the factors that have a big impact on infertility, as many of the strategies that were used to make that happen are heavily weighted in that way. With the help of various data mining and machine learning approaches, a lot of studies have been done to estimate the success rate of IVF based on these characteristics. Because of the decades of advancement in the field of science and computation, AI has gained popularity across all the technological fields. The advancement of the medical sciences and of clinical practises is so affected. Prediction and assessment form the foundation of any medical application right now. In order to evaluate it from a medical perspective and find out how beneficial it is. C. Siristatidis used statistical modelling and logistic regression [13]. Human inference is virtually eliminated in Artificial Neural Networks (ANN) because they have a full solution. It is capable of future analysis and forecasting. According to the information below, ANN is also used in the field of gynecology.

The field of infertility is also impacted by artificial intelligence. During an IVF cycle, an embryologist will

frequently perform embryo morphology. To discover the best embryo, an embryologist must perform a crucial task called embryo grading. However, if the implantation is unsuccessful, the patient will need to undergo additional testing in order for the transfer to be successful. The number of cycles the patient should undergo, however, is unpredictable. If the computer has been provided with the patient's microscopic photos (blastocyst), [14] it will use AI to estimate the best embryo that will produce an accurate outcome for fertility treatment.

1. Image Source: Medical express

The convolutional neural network model has been presented for automatically determining the grade of the blastocyst using image processing. A deep neural network called STORK, created by Weill Cornell Medical College, allows for the automation of the infertility process in terms of selecting and transferring embryos. Time lapse imaging is employed to evaluate the optimal embryo growth. A critical component of the evaluation of the embryo quality is the classification of oocyte and embryos. The greatest results are obtained when this classification is automated utilizing AI technology as opposed to previously applied ML methods[15]. Infertility results from chromosomal abnormalities. The patient and fertility specialists will save money and time if this is discovered before the IVF procedure. Aneuploidy can be address with AI. This can be anticipated before treatment once the blastocyst image is created and sent to the AI network.

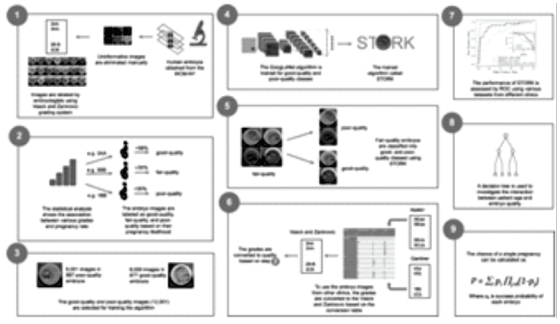

Figure 2: The STORK flowchart: This flowchart illustrates the design and assessment of STORK

2. AI in embryo Grading

The time-consuming and crucial task of the infertility procedure is embryo grading, where the final optimal embryo selection will be made after the study and processing of embryo qualities. Deep learning employs its methods to speed up the evaluation of embryos. The estimated one million embryos employed in this study are five days old. Three categories – training, validation, and testing – were applied to the photos. The network employed for this investigation has fifty tiers [16]. The optimal embryo to transfer for the treatment has been recommended by the network after an automated evaluation of the available embryos. The amount of time and clinical duties required is greatly decreased as a result. To compare the crucial characteristics of the embryos that can be used for the procedure, you can use semi-automated grading. Segmenting and analyzing images are included in this.

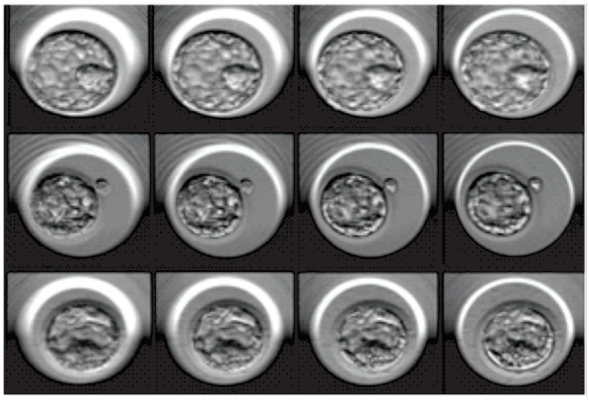

Figure 3: AI in Embryo Grading

3. AI in embryo Classification

Following grading, embryo selection is the most crucial step. To choose an embryo with the best possibility of being fertile, it is basically necessary to know what day it is. The evaluation employs the cohort embryo selection approach, which takes into account the time and date of the embryos that are most likely to implant. This is an innovative and straightforward technique for high-quality embryo analysis.

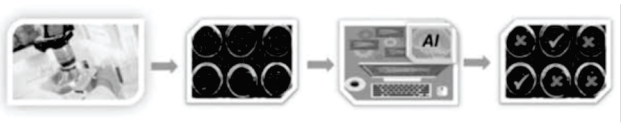

Figure 4: Classification of Blastocyst images using AI

VII CONCLUSION

Artificial Intelligence will lead to a digital revolution and several advancements in the field of reproductive medicine, which will ultimately be extremely beneficial to both society and infertile patients. The use of AI in IVF is crucial and offers advantages for embryo grading and selection, as well as for enhancing the evaluation of ovarian reserve characteristics and sperm selection.

The primary goal of this novel approach is to be used in more extensive and structured investigations, such as those involving single-embryo transfers, and to include a prospective arbitrary trial to ensure complete clinical relevance. Convolutional neural networks are used in deep learning applications in AI to create classifiers that forecast birth potential using blastocyst images that have been categorised according to the maternal age. According to the current model's study, machine learning and artificial intelligence are significant. These methods of ART treatment have been found to be the most reliable ones. Most research focuses on traits or limitations that cause infertility. These models can be updated using the most recent information by using the dataset of blastocyst images, which is a proposed task. This ground-breaking study provides you with a preview of how the area will benefit future generations. There isn't much literature available in this area of expertise because of this subject: neural network based embryonic quality assessment is still in its infancy.

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