International Journal of Engineering Technology and Management Sciences
Website: ijetms.in Issue: 5 Volume No.6 Aug-Sept – 2022
DOI:10.46647/ijetms.2022.v06i05.042 ISSN: 2581-4621

A Review on AI methods for the Prediction of Infertility in Women

Soumya Koshy[1], Dr. K. Anuradha[2]
[1] *Research Scholar, Karpagam Academy of Higher Education, Coimbatore*
[2] *Professor, Dept. of Computer Science, Karpagam Academy of Higher Education, Coimbatore*

ABSTRACT

Around the world 8 to 15 percent of couples in their reproductive age have infertility problem. According to WHO estimates, there are 60-80 million infertile couples globally, with some parts of population having the greatest rate. Significant social, emotional and psychological stress has been brought on by infertility among couples, families, the individual in question, and the larger society. Few researches have used Artificial Intelligence (AI) techniques in the field of reproduction, despite the fact that the use of AI techniques in the medical profession is growing every year. In order to assist couples with unexplained infertility, this review study develops and assesses multiple artificial intelligence models that can differentiate infertile/fertile couples based on a variety of characteristics.

Keywords - Infertility, Machine learning, Artificial Intelligence, Deep Learning, Image Processing, Convolutional Neural Network(CNN)

1. INTRODUCTION

Failure to become conceived after 12 months of unprotected sexual intercourse is termed infertility. The World Health Organization (WHO) states that infertility is a condition that results in disability as function impairment. More than 186 million couples worldwide struggle with infertility, and indeed majority of them live in impoverished countries without access to adequate care. Infertility is therefore one of the most prevalent health issues in the world.

According to the literature, various research studies have attempted to predict infertility outcomes using machine learning approaches. It is clear from a qualitative and quantitative analysis of the reviews that a variety of classifiers are employed to predict infertility, but only a small amount of static data from fertility clinics is used to train them. By providing the classifier with lot of dynamic data during training, the accuracy of the infertility prediction may be increased. However, the methods now in use make creating such a classifier challenging. Big Data Analytics in infertility allows for this.

The machine learning (ML) technique of predictive analysis gives healthcare workers improved information. This helps individuals make wiser choices, which raises the success rate of infertility treatments.

In order to find potential extensions, either to fill the gap or advance the research, the goal of this review paper is to understand the current status of the research in the prediction of infertility using various Artificial Intelligent techniques that may comprise various Machine Learning methods. Several publications on machine learning and inferfility are reviewed for this aim. We only choose research papers that use machine learning to predict infertility. Then these papers are examined to help future researchers uncover the necessary improvements in their subsequent research as well as to help them better comprehend machine learning for infertility.

In this paper we present a review of six distinct publications on artificial intelligence based infertility prediction.

The article is organized as; section 2 provides an overview of Artificial Intelligence, section 3 describes the selected models, the methods used and analysis of each model, the fourth section provides the summary of the overall study and the fifth section concludes the paper.

International Journal of Engineering Technology and Management Sciences
Website: ijetms.in Issue: 5 Volume No.6 Aug-Sept – 2022
DOI:10.46647/ijetms.2022.v06i05.042 ISSN: 2581-4621

2. OVERVIEW OF ARTIFICIAL INTELLIGENCE METHODS

For a deeper understanding of the section to follow, this section will give an overview of artificial intelligence methods [1] and the major Machine Learning Method and Deep Learning Method used in the various survey papers.

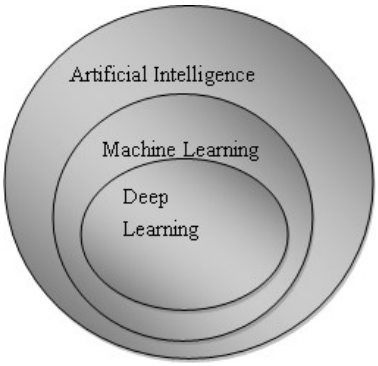

Figure 1: Relationship between AI, ML and DL

Any computer model with a trace of human intelligence is referred to as AI, which also incorporates ML and DL.

2.1 Artificial Intelligence

Machines that demonstrate intelligence are said to have artificial intelligence (AI) [2]. In computer science, the study of "intelligent agents": anything that can sense its environment and take actions to increase its chances of success-is what is meant by the term.

When a machine imitates "cognitive" processes that people typically connect with other human minds, such as "learning" and "problem solving," the phrase "artificial intelligence" is used.

2.2 Machine Learning

Machine learning is a kind of artificial intelligence that gives computers the skills they need to enhance their analysis based on historical data. These computer systems use historical information from earlier attempts to complete a task to increase effectiveness in successive iterations of a task of a similar nature. Machine learning relies largely on statistical modelling approaches since it aims to extract knowledge from raw data. Pattern recognition and probability theory are also favourable to machine learning. Machine learning is utilized in the data analytics industry to create intricate models and algorithms that are conductive to prediction; this process is referred to as predictive analytics commercially.

2.2.1. Types of machine learning

Numerous algorithms are used in machine learning to complete various tasks. The algorithm's goal is to create a model that fits the data. Figure 2 illustrates the classification, regression, clustering and association rule learning process that make up machine learning.

Data are mapped into specified categories or classes through classification. Because the classes are established prior to looking at the data, it is frequently referred to as supervised learning. Regression chooses the optimal function for the provided data under the presumption that the target data fit into some form of known function (linear, logistic etc..). Clustering is an unsupervised learning technique where the most related data are grouped together into clusters based on how similar they are across predetermined attributes. A model known as an association rule detects particular kinds of data associations.

2.3 Deep Learning

Deep learning is the study of artificial neural networks and related machine learning algorithms that incorporate more than one hidden layer. It is sometimes referred to as deep structured learning, deep hierarchical learning or deep machine learning. Two sets of neurons may exist in a simple scenario: a set that receives input signals and a set that sends output signals. A modified version of

International Journal of Engineering Technology and Management Sciences
Website: ijetms.in Issue: 5 Volume No.6 Aug-Sept – 2022
DOI:10.46647/ijetms.2022.v06i05.042 ISSN: 2581-4621

the input is sent to the subsequent layer by the input layer when it gets an input. The input and output in a deep network are separated by a number of layers.

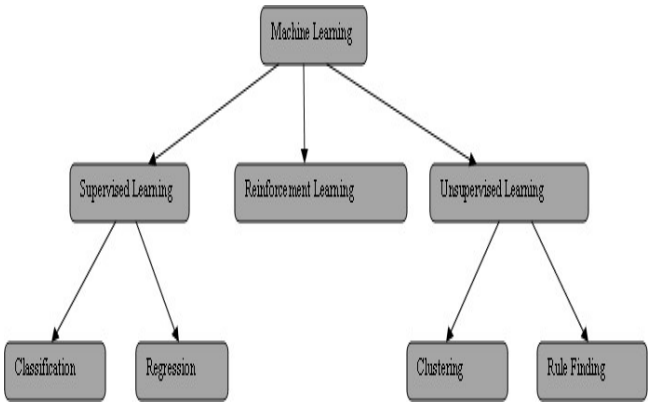

Figure 2: Types of machine learning

3. OVERVIEW OF MODELS

The following section explains several models used for the investigation along with their topographies. To predict female infertility, each of these models employs different machine learning and deep learning methodologies. They differ in terms of the architecture they employ and the data collection used for investigation.

3.1 Sofiane Bendifallah

In this paper [3], machine learning algorithms (MLA) are utilized based on 16 important clinical and patient-based symptom criteria for the detection and screening of endometriosis. Data obtained between January 2021 and May 2021 from the open health platform Ziwig Health served as the training dataset for this study.

The five basic machine learning models used here are: Random Forest (RF), Decision Tree (DT), eXtreme Gradient Boosting (XGB) and hard/soft Voting Classifier. To create the diagnostic model, 1126 and 608 patients with and without endometriosis were retrieved from the Ziwig Health platform (training set). Additionally 100 patients from the prospective cohort were employed as the validation set. Among these 100 patients in the validation cohort, 87% (n=87) had endometriosis and 13% (n=13) did not (controls).

Among all the Machine Learning Models used, the most accurate methods found in this study are Soft Voting Classifier, RF and XGB, with a sensitivity and specificity values of between 95 and 98 percent and 80 percent respectively.

Model used	**Training set**			
	Sensitivity	Specificity	F1-score	AUC
Random Forest(RF)	0.98	0.8	0.88	0.89
Logistic Regression	1	0	0	0.5
Decision Tree (DT)	0.82	0.8	0.81	0.82
eXtreme Gradient Boosting (XGB)	0.98	0.8	0.88	0.89
Voter Classifier Soft	0.98	0.6	0.74	0.75
Voter Classifier Hard	0.95	0.8	0.87	0.88

Table 1: Classification metrics of the training set

International Journal of Engineering Technology and Management Sciences
Website: ijetms.in Issue: 5 Volume No.6 Aug-Sept – 2022
DOI:10.46647/ijetms.2022.v06i05.042 ISSN: 2581-4621

Model used	Validation set			
	Sensitivity	Specificity	F1-score	AUC
Random Forest(RF)	0.92	0.92	0.92	0.92
Logistic Regression	0.95	0.81	0.87	0.88
Decision Tree (DT)	0.91	0.66	0.77	0.78
eXtreme Gradient Boosting (XGB)	0.93	0.92	0.92	0.93
Voter Classifier Soft	0.93	0.88	0.9	0.90
Voter Classifier Hard	0.91	0.92	0.91	0.92

Table 2: Classification metrics of the validation set

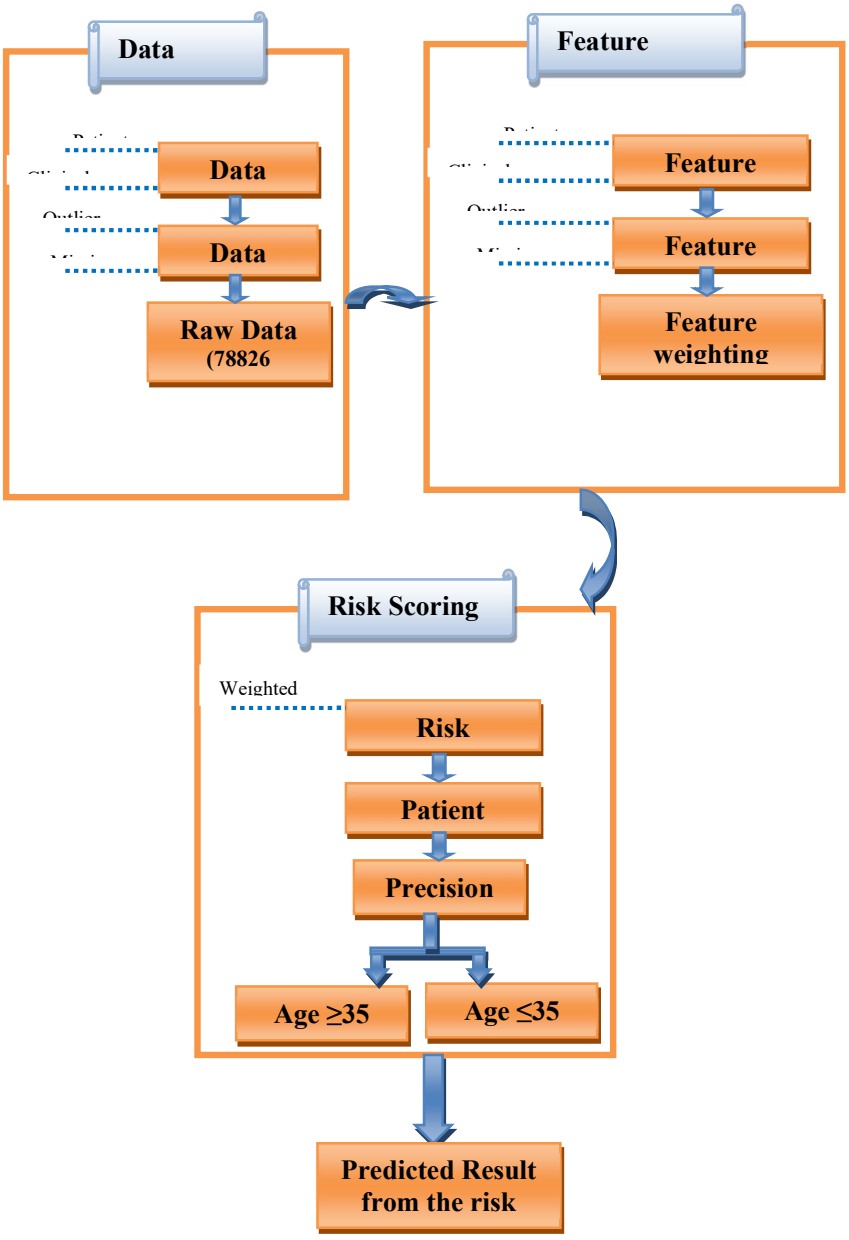

Figure 3: Implementation phases of the Risk Scoring System

International Journal of Engineering Technology and Management Sciences
Website: ijetms.in Issue: 5 Volume No.6 Aug-Sept – 2022
DOI:10.46647/ijetms.2022.v06i05.042 ISSN: 2581-4621

3.2 ShuJie Liao

In this model [4], a machine learning based risk point system for infertility was created to aid clinicians in better understanding the patient's condition in context of the intricacy of infertility management and therapy. First, feature selection excludes eight crucial indicators of infertility. Second, the entropy-based feature discretization approach was applied to divide the feature abnormal intervals and the random forest was used to estimate the weight of each feature. Last but not least, depending on the patient's overall risk score, the pregnancy outcome can be forecasted, which aids clinicians in making more effective treatment decisions.

The medical records of 78,826 infertile individuals were examined, and eight essential characteristics were eliminated. The risk score was computed using the RF algorithm and an entropy-based feature discretization technique. The corresponding risk assessment system for patients of various ages was also developed in this paper. Age, FSH, AFC, AMH, inhibin B, type of infertility, duration of infertility, and progesterone are the eight major components of the risk scoring system for infertility.

3.3 S. Visalaxi

Image clarity (characteristics) was improved to aid the surgeon in spotting the presence of endometriosis. Deep learning is capable of recognizing and classifying images. On massive datasets, the Convolutional Neural Networks (CNNs) can be used to classify images. The suggested system [5] measures performance using a cutting edge method that applies the transfer learning model to the well known ResNet50 architecture. In comparison to previous transfer learning strategies, the suggested method performs better utilizing ResNet50.

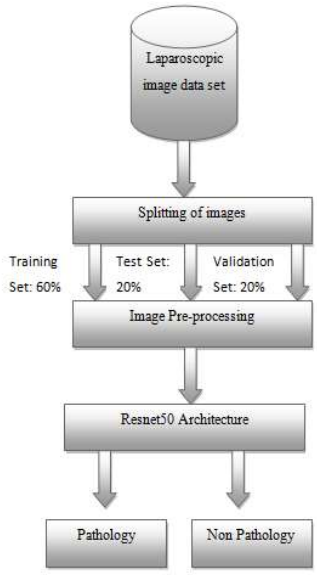

Figure 4: Methodology for Recognizing Laparoscopic Images Using ResNet50 Architecture

The trained model is tested using the input images, and it was then utilized to categorize the images as pathological and non-pathological. Laparoscopic images were divided into independent training, test and validation groups when designing the neural network model's architecture.

VGG16, Inception V3, ResNet50, Xception and InceptionResNetV2 are a few of the different transfer learning methods. In table 3, the accuracy, sensitivity and specificity of several transfer learning strategies are compared. ResNet50 operates well with the provided data set.

International Journal of Engineering Technology and Management Sciences
Website: ijetms.in Issue: 5 Volume No.6 Aug-Sept – 2022
DOI:10.46647/ijetms.2022.v06i05.042 ISSN: 2581-4621

Transfer Learning	Sensitivity(%)	Specificity(%)	Accuracy(%)
ResNet50	82	72	92
VGG16	76	70	80
Inception V3	80	75	81
Xception	78	71	83.5
Inception ResNet V2	75	70	88

Table 3: The impact of several transfer learning methods for detecting endometriosis

The goal of this investigation is to identify endometriosis. It was accomplished by utilizing a Convolutional Neural Network and Transfer Learning (CNN). The proposed CNN could identify between tissues that were not endometriotic and those that were. In this study, the ResNet50 design did a good job of predicting the likelihood of endometriosis. The estimated model accuracy for the suggested system was 90%. Precision is 83%, recall is 82%, F1 score is 82% and AUC is 78% for the model.

3.4 Jeremiah Ademola Balogun

In order to develop predictive models for the likelihood of infertility in women, this paper [6] presents a comparative analysis of three (3) supervised machine learning models: naive Bayes, decision trees and multi-layer perceptron algorithm. The goal is to suggest the most effective and efficient model. Factors that are important for determining a woman's chance of infertility along with the relationship that underlies them are also suggested.

In order to complete this study, it was required to locate and gather the information from gynaecologists at the Obafemi Awolowo University Teaching Hospital Complex (OAUTHC) and the Obafemi Awolowo University, Ile-Ife Faculty of Health Sciences.

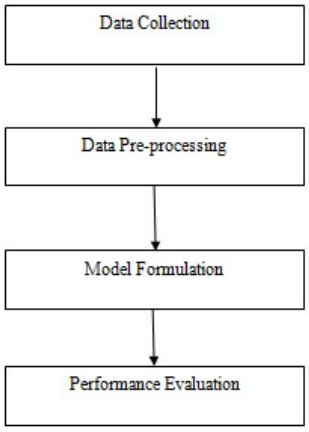

Fig 5: The difference phases in this model

The dataset containing the risk factor records for 39 patients was used to train the construction of three separate supervised machine learning algorithms, which were then utilized to formulate the predictive model for the likely hood of infertility. The Waikato Environment for Knowledge Analysis was used to simulate the prediction models (WEKA).

The naive Bayes algorithm was implemented using the naive Bayes classifier available in the Bayes class, the multilayer perceptron algorithm was implemented using the multilayer perceptron classifier available in the functions class, and the C4.5 decision trees algorithm was implemented using the J48 decision trees algorithm available in the tree class, all of which were available of the WEKA environment of classification tools.

International Journal of Engineering Technology and Management Sciences
Website: ijetms.in Issue: 5 Volume No.6 Aug-Sept – 2022
DOI:10.46647/ijetms.2022.v06i05.042 ISSN: 2581-4621

Model used	Accuracy	TP Rate	FP Rate	Precision
Naive Bayes	71.795	0.718	0.201	0.699
Decision Trees	74.359	0.744	0.203	0.704
Multi-layer Perceptron	74.359	0.744	0.119	0.787

Table 4: Overview of the simulation outcomes

Because of its high accuracy, TP rate and Precision with a low value for the FP rate, the multi-layer perceptron (MLP) is the most efficient supervised machine learning method, according to the simulation findings.

3.5 Simi M S

Predictive modelling now allows for a more accurate diagnosis of conditions like infertility, which are challenging to identify or diagnose. In this paper [7] we take into account 26 variables in this research and pinpoint pertinent variables for the early detection of 8 different kinds of female infertility.

The process of creating practical insights by defining problems, applying statistical models and analysing existing data is known as data analytics. The analysis of this vast amount of data can be used to develop knowledge that aids in the quicker and more accurate diagnosis of some diseases.

Finding the correct data set is a significant challenge from the perspective of data analytics, particularly in the case of infertility. The information is collected from Sabine Hospital & Research Centre. There are 26 attributes and 965 instances of this.

To assess the precision of the predictions, the full dataset was subjected to two classification techniques, Random Forest and J48 approaches. From among the variables selected, the key variables set as biomarkers are 12.

Classifier Methods	Accuracy
J48	87.7%
Random Forest (RF)	88.7%

Table 4: Ten Fold using Biomarker variables

According to the simulation results, Random Forest using biomarkers as predictors is the best and most appropriate prediction method for infertility. It can be utilised for early infertility detection as well as to assist clinical practitioners in their decision making.

3.6 Amsy Denny

This paper [8] suggests a system for early identification and prediction of PCOS using ideal, minimum and promising clinical and metabolic indicators that server as a disease's early marker. The 541 women who participated in a patient survey conducted during medical consultations and clinical examinations provided the data sets needed for the development of the system. Using SPSS V 22.0, 8 probable features are found out of the 23 characteristics from clinical and metabolic test data based on their importance. Several machine learning techniques, including the Naive Bayes classifier method, Logistic Regression, K-Nearest neighbour(KNN), classification and Regression Trees (CART), Random Forest Classifier and Support Vector Machine (SVM) in Syder Python IDE are used to classify PCOS using the feature set transformed with Principal Component Analysis (PCA).

International Journal of Engineering Technology and Management Sciences
Website: ijetms.in Issue: 5 Volume No.6 Aug-Sept – 2022
DOI:10.46647/ijetms.2022.v06i05.042 ISSN: 2581-4621

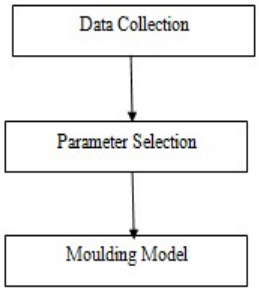

Figure 6: The different Phases involved in finalizing the model

It was possible to investigate a total of 541 cases which were gathered from various infertility treatment centres in Thrissur. The data included women between the ages of 18 and 40.

The chosen methods are a combination of straightforward linear and non-linear algorithms. LDA and LR are two straightforward linear algorithms. KNN, CART, RFC, NB and SVM are non-linear algorithms. Each of the models accuracy estimation was performed. This leads us to the conclusion that the Random Forest Classifier model which had an accuracy of 89% after data optimization provided the best performance.

Model used	Accuracy
Logistic Regression (LR)	0.8536
K- Nearest Neighbors (KNN)	0.8658
Classification and Regression Trees (CART)	0.8292
Random Forest Classifier (RFC)	0.8902
Gaussian Naïve Bayes (NB)	0.8414
Support Vector Machines (SVM)	0.8292

4. RESULTS AND DISCUSSION

Infertility prediction studies employing various machine learning algorithms were examined in six separate research in this paper. The machine learning model utilised, the training data set, and the metrics used to evaluate these models vary amongst different models. In this work, we are trying to find out the performance each of these models based on various performance measurement.

Ref #	Area	Methods used	Dataset used	Outcome
3	Machine Learning	Random Forest (RF), Decision Tree (DT), eXtreme Gradient Boosting (XGB) and hard/soft Voting Classifier, Logistic Regression	Ziwig Health platform	Among all the models used Soft Voting Classifier, RF and XGB give accurate results
4	Machine Learning	RandomForest (RF)Entropy-based feature discretization technique	Reproductive Center of Tongji Hospital, Tongji Medical College Affiliated with Huazhong University of Science and Technology in	Propose a risk scoring system for predicting infertility

DOI:10.46647/ijetms.2022.v06i05.042 ISSN: 2581-4621

			Wuhan, China, from 2006 to 2020.	
5	Deep learning	ResNet50, VGG16 Inception V3 Xception Inception ResNet V2	Standardised Laparoscopic images from GLENDA: Gynaecologic Laparoscopy Endometriosis Dataset	ResNet50 Architecture (Accuracy: 90%)
6	Machine Learning	Naive Bayes, decision trees and multi-layer perceptron algorithm	Obafemi Awolowo University Teaching Hospital Complex (OAUTHC) and the Obafemi Awolowo University, Ile-Ife Faculty of Health Sciences.	Multi-layer perceptron (MLP)
7	Machine Learning using Predictive Modelling	J48, Random Forest	Sabine Hospital & Research Centre, Muvattupuzha	Random Forest (88.7%)
8	Machine Learning	LDA, LR ,KNN, CART, RFC, NB and SVM	Various infertility treatment centres in Thrissur.	Random Forest (89.2%)

5. CONCLUSION

Infertility is a major problem that affects the physical, mental and social condition of a person that may lead to various serious impacts or issues to the family, society, work conditions etc...Early prediction of infertility can very much contribute to the Medical field and improve physical, mental and social conditions of a patient. With the evolution of AI, a lot of studies are ongoing to detect, analyse and predict infertility at an early stage. In this paper, we have done a review of six different models for the prediction of infertility using various machine learning and Deep Learning Models. Each of these models used different architectural models. As per our study, it was observed that accuracy of prediction was shown to be best in Random Forest in almost all machine learning models and ResNet50 Architecture in CNN.

REFERENCES

1. Ranjini, K., A. Suruliandi, and S. P. Raja. "Machine learning techniques for assisted reproductive technology: A review." Journal of Circuits, Systems and Computers 29.11 (2020): 2030010.
2. Ongsulee, Pariwat. "Artificial intelligence, machine learning and deep learning." *2017 15th international conference on ICT and knowledge engineering (ICT&KE)*. IEEE, 2017.
3. Bendifallah, Sofiane, et al. "Machine learning algorithms as new screening approach for patients with endometriosis." *Scientific Reports* 12.1 (2022): 1-12.
4. Liao, ShuJie, et al. "A machine learning-based risk scoring system for infertility considering different age groups." *International Journal of Intelligent Systems* 36.3 (2021): 1331-1344.
5. Visalaxi, S., and T. Sudalai Muthu. "Automated prediction of endometriosis using deep

DOI:10.46647/ijetms.2022.v06i05.042 ISSN: 2581-4621

learning." *International Journal of Nonlinear Analysis and Applications* 12.2 (2021): 2403-2416.
6. Balogun, Jeremiah Ademola, Ngozi Chidozie Egejuru, and Peter Adebayo Idowu. "*Comparative analysis of predictive models for the likelihood of infertility in women using supervised machine learning techniques.*" Computer Reviews Journal 2.1 (2018): 313-330.
7. M. S. Simi, K. S. Nayaki, M. Parameswaran and S. Sivadasan, "Exploring female infertility using predictive analytic," *2017 IEEE Global Humanitarian Technology Conference (GHTC)*, 2017, pp. 1-6, doi: 10.1109/GHTC.2017.8239343.
8. A. Denny, A. Raj, A. Ashok, C. M. Ram and R. George, *"i-HOPE: Detection And Prediction System For Polycystic Ovary Syndrome (PCOS) Using Machine Learning Techniques*," *TENCON 2019 - 2019 IEEE Region 10 Conference (TENCON)*, 2019, pp. 673-678, doi: 10.1109/TENCON.2019.8929674.
9. Durairaj, M., and R. Nandhakumar. *"Data mining application on ivf data for the selection of influential parameters on fertility." Int J Eng Adv Technol (IJEAT)* 2.6 (2013): 262-266.
10. Bachelot, G., Lévy, R., Bachelot, A. et al. "Proof of concept and development of a couple-based machine learning model to stratify infertile patients with idiopathic infertility". Sci Rep 11, 24003 (2021). https://doi.org/10.1038/s41598-021-03165-311.
11. Mehrjerd, A., Rezaei, H., Eslami, S. et al. "Internal validation and comparison of predictive models to determine success rate of infertility treatments: a retrospective study of 2485 cycles." Sci Rep 12, 7216 (2022). https://doi.org/10.1038/s41598-022-10902-9
12. Vats, Sakshi, et al. "Combination of Expression Data and Predictive Modeling for Polycystic Ovary Disease and Assessing Risk of Infertility Using Machine Learning Techniques." Innovations in Computational Intelligence and Computer Vision. Springer, Singapore, 2022. 547-555.
13. Nandipati, Satish CR, C. X. Ying, and Khaw Khai Wah. "Polycystic Ovarian Syndrome (PCOS) classification and feature selection by machine learning techniques." Appl Math Comput Intell 9 (2020): 65-74.
14. Wang, Cheng-Wei, et al. "Predicting clinical pregnancy using clinical features and machine learning algorithms in vitro fertilization." PloS one 17.6 (2022): e0267554.
15. Tadepalli, Satya Kiranmai, and P. V. Lakshmi. "Application of Machine Learning and Artificial Intelligence Techniques for IVF Analysis and Prediction." International Journal of Big Data and Analytics in Healthcare (IJBDAH) 4.2 (2019): 21-33.