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A Survey on Machine Learning in Forecasting Success in Intrauterine Insemination

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Abstract- This survey paper aims to provide a comprehensive overview of the current state of research regarding the utilization of machine learning in forecasting the success of Intrauterine Insemination procedures (IUI). The discussion commences with an exploration of the fundamental concepts and advantages in IUI, as well as the challenges associated with predicting success. Next, the various Machine Learning approaches, including supervised, unsupervised, and deep learning techniques utilized in this context, are explored. Furthermore, an examination is conducted on the critical factors and features considered in the development of predictive models, such as patient age, hormonal profiles, cycle characteristics, and sperm analysis. Additionally, it is found that there may be potential benefits in incorporating, lifestyle, emotional, yoga and meditation factors into predictive models to enhance their accuracy.
Keywords: Artificial Intelligence, Infertility, Machine Learning, ART, IUI, Deep Learning

1. Introduction

The failure of conception after regular, unprotected sexual activity for a period of 12 months without the use of contraception is considered infertility[1].

According to a report released by the WHO in April 2023, approximately 1 in 6 adults globally struggle with infertility[2]. Infertility affects approximately 48 million couples and 186 million individuals worldwide [3,4]. The occurrence of infertility across India is declined between 1992-93 and 2005-06, but it notably surged in 2015–16. In comparison to 2005–06, there has been a substantial rise in infertility rates in 2015-16, particularly in the Southern states of India [5].

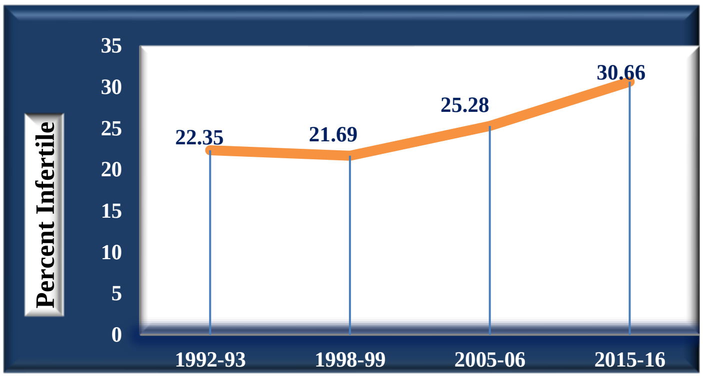

Fig 1: The patterns that indicate the extent of infertility in India [5].

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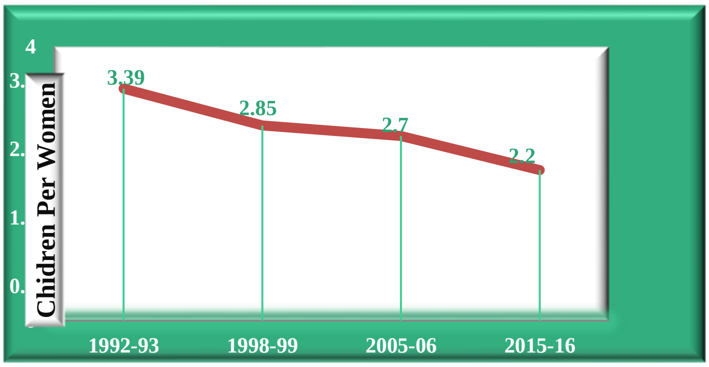

Fig 2: Patterns of the overall fertility rate in India [5]

The graph in Figure 1 illustrates the trajectory of infertility and Figure 2 indicates the the total fertility rate (TFR) in India. Both of which experienced significant decreases until 1998–99. However a certain sharp rise in infertility, accompanied by another decline in TFR between 2005–06 and 2015–16.

Studies exhibited that, menstrual problems, illnesses (diabetes, obesity and thyroid disorders), ovulation dysfunction, uterine factor, fallopian tubes, and cervical factor were the most common reasons of female infertility, and semen fluid abnormalities, genetic factors, vascular abnormalities, and anti-spermatogenesis factors were the most frequent causes of male infertility[6–8].

Numerous psychosocial issues, including anxiety, nervousness, sadness, loneliness, and social isolation, can be driven due to infertility. Most of the culture treats infertile couples with disrespect and shame because it perceives their infertility as a punishment [9–11].

Assisted Reproductive Technology (ART) plays a crucial role in helping infertile couples in achieve pregnancy [12]. Intrauterine Insemination (IUI) can be counted as a ART and studies reccomends IUI as a Strong front-line approach for the couples with minor fertility problems [13,14].

Success rates of IUI can be affected by a multitude of variables, including age of the woman, sperm quality, ovarian function, underlying fertility issues, and the number of previous IUI cycles attempted [15,16].

Since various biochemical indicators are necessary to evaluate infertility, comprehensive assessment strategies must be used. Therefore, algorithmic protocols that incorporate these biochemical characteristics in a dynamic testing environment are required to give infertile couples a more thorough diagnostic evaluation and more successful treatment plan [17,18].

Artificial intelligence (AI) and machine learning (ML) are transforming healthcare by enabling data-driven decision-making, enhancing diagnostic accuracy, and personalizing treatment plans. AI algorithms can analyze vast medical datasets, identify patterns, and predict patient outcomes, aiding healthcare professionals in making more precise diagnoses and treatment recommendations Additionally, ML models are instrumental in drug discovery, patient risk assessment, and the development of predictive healthcare tools. The synergy of AI and ML holds the potential to revolutionize healthcare by improving patient care, reducing costs, and advancing medical research[19–24].

The ML algorithms shall reduce the time and efforts of medical practitioners in the diagnosis of disease since the results obtained from ML algorithms are compared with gold standarads and also proven that they have good classifactuiion accuracy and kappa [25].

Therfore the aim of this review is to explore the multifaceted applications of ML within the realm of assisted reproduction techniques, with a specific focus on IUI. By analyzing the current state of research and technology, we aim to elucidate the potential benefits, challenges, and future prospects of integrating ML into IUI procedures, ultimately aiming to enhance the success rates and outcomes in IUI.

2. Assisted Reproductive Techniques (ART'S):

ART's are medical procedures designed to help individuals or couples to overcome infertility and to have children. ART procedures typically involve the manipulation of eggs, sperm, or embryos outside of the body to facilitate conception [26]. They are used when natural conception is difficult or impossible due to factors like infertility, medical conditions, or genetic concerns, providing hopeful parents with the opportunity to start or expand their families. The various ARTs are [27,28] :

i) In Vitro Fertilization (IVF)
ii) Intracytoplasmic Sperm Injection (ICSI)
iii) Gamete Intrafallopian Transfer (GIFT)
iv) Zygote Intrafallopian Transfer (ZIFT)
v) Intravaginal Culture (IVC)
vi) Intrauterine Insemination (IUI)
vii) Preimplantation Genetic Testing (PGT)
viii) Surrogacy
ix) Ovulation induction
x) Cryopreservation

i) In Vitro Fertilization (IVF) involves the fertilization of eggs with sperm outside the woman's body in a lab dish. Once fertilization occurs and embryos develop, one or more healthy embryos are implanted into the the woman's uterus [29,30].

ii) Intracytoplasmic Sperm Injection (ICSI) is a specialized form of IVF where a single sperm is directly injected into an egg to facilitate fertilization, especially useful when male infertility is a concern [31,32].

iii) Gamete Intrafallopian Transfer (GIFT), ın whıch both the sperms and eggs are collected and placed directly into the fallopian tubes, allowing fertilization to occur naturally inside the woman's body [33].

iv) Zygote Intrafallopian Transfer (ZIFT) is similar to GIFT, but in this procedure, fertilization is allowed to happen in the laboratory, and the resulting fertilized embryos are inserted into the fallopian tubes [34].

v) Intravaginal Culture (IVC) involves placing sperm and eggs into a small container (culture dish), which is then inserted into the woman's vagina to allow fertilization to occur inside the body [35].

vi) Intrauterine Insemination (IUI) involves placing sperm directly into the woman's uterus during ovulation to improve the probability of fertilization [36].

vii) Preimplantation Genetic Testing (PGT) is a technique used in conjunction with IVF to screen embryos for genetic abnormalities or chromosomal disorders before implantation, helping to designate healthy embryos for transplantation [37].

viii) Surrogacy is an arrangement in which another woman (the surrogate) carries and gives birth to a child for individuals or couples who have difficulty conceiving or carry a pregnancy themselves [38].

ix) Ovulation induction involves the utilization of hormonal medications to stimulate the ovaries to produce and release eggs, increasing the chances of conception [39].

x) Cryopreservation, also known as embryo freezing, involves freezing and storing surplus embryos from IVF cycles for future use [40].

In vitro fertilization (IVF), along with its advanced variations like intracytoplasmic sperm injection (ICSI), intrauterine insemination (IUI), zygote intrafallopian transfer (ZIFT), and gamete intrafallopian transfer (GIFT), ranks among the most widely practiced ARTs worldwide [41–44].

TABLE 1: COMPARISON OF COST AND COMPLEXITY AMONG POPULAR ARTS [45–47].

ART Technique	Complexity	Duration	Cost
IVF	Relatively complex	Several weeks to a few months	More expensive
ICSI	Highly specialized procedure that is performed as part of an IVF cycle	Timeline is similar to IVF	More expen-sive
GIFT	Moderately complex	Timeline is similar to IVF with Additional steps	More expen-sive
ZIFT	Moderately complex	Timeline is similar to IVF with Additional steps	More expen-sive
IUI	Less complex	Shorter time	More afforda-ble

Table 1 shows an analysis of cost and complexity among the commonly used ARTs. The complexity and cost of ART procedures generally follows the order from most complex to least complex as IVF, ICSI, GIFT/ZIFT, and IUI. IVF and ICSI are more intricate and involve multiple stages and laboratory processes, while GIFT and ZIFT involve surgical procedures. IUI is the least complex, involving a less invasive process with fewer steps.

3. CHALLENGES IN PREDICTION OF IUI SUCCESS

IUI is a less invasive, more affordable and includes short procedure compared to other ART methods. More importantly IUI is a natural conception process since it facilitates the natural sperm journey toward the egg [48–51]. The outcome of IUI affected by various factors such as:

i) Female partner age.
ii) Regular ovulation of female partner.
iii) Quality and quantity of sperm from the male partner
iv) Woman's fallopian tubes condition
v) Cervical Factors including cervical mucus issues
vi) Accurate prediction the timing of ovulation
vii) Couple's previous fertility treatment history
viii) Lifestyle factors such as smoking, alcohol use
ix) Body Mass Index (BMI) [52,53].

There are currently no universally accepted biomarkers or definitive predictors that Can assess IUI success with accuracy. While certain factors like age and sperm parameters offer some perspective, but it's inadequate on their own to reliably predict the outcome [54].

The difficulty in predicting the success of IUI primarily stems from multiple variables and individual variability since each patient's response to IUI can vary widely and factors such as hormonal levels, uterine conditions, and cervical mucus quality vary significantly among person to another [55,56].

While medical professionals can rely on historical success rates for IUI, these statistics might not entirely capture the nuances of individual cases. Clinical information may not encompass every relevant patient-specific factors that impact success [57].

The emotional and psychological aspects of fertility treatment can influence outcomes. Stress, anxiety, and emotional well-being can affect a patient's response to treatment, which is challenging to quantify [58].

Due to these complexities and the unique nature of each patient's situation, accurately predicting the success of IUI remains a formidable challenge for healthcare providers.

4. Machine Learning in the Prediction of success of IUI

This section consists review of existing knowledge on Machine Learning in forecasting success in Intrauterine Insemination (IUI). We comprehensively anlyzed 9 articles.

In these studies an array of factors are considered and incorporated into the analysis. These factors typically encompass both patient-specific variables and clinical parameters. A compilation of the included factors is presented in Table 2. The study region, Number of participants / IUI Cycles incorporated, AI or ML algorithms applied and their accuracy is tabulated in Table 3.

In the landscape of fertility research, various ML algorithms have been employed by researchers to forecast the outcome of IUI. These algorithms encompass a diverse array of techniques, including support vector machines, logistic regression, random forests, artificial neural networks, , and gradient boosting, among others.

Each of these algorithms brings its own unique computational approach and mathematical framework to the task of analyzing complex datasets related to IUI outcomes.

The literature reflects a growing interest in harnessing the predictive power of ML, as these algorithms offer the potential to uncover hidden patterns, identify crucial variables, and enhance the accuracy of success predictions in IUI, ultimately contributing to more informed clinical decision-making in the realm of fertility treatments.

Small sample size of individual indicators in specific ranges, regional and population constraints due to data coming solely from a single hospital's medical records, lack of external validity are some of the limitations of these studies

Table 2: Factors considered in ML techniques for prediction of success in IUI

Factors	Female Age	Male Age	BMI	Harmone Analysis	Follicular Study	Semen Analysis	Abortion History	Menstruation factors	Psychological and emotional aspects	Lifestyle	Yoga/ Meditation	IUI Cycles
Michal youngster et.al [59]				✓								
Changbo Jin et.al [60]	✓	✓	✓		✓	✓	✓	✓				✓
Sajad Khodabandelu et.al [61]	✓	✓		✓	✓	✓		✓				✓
Ameneh Mehrjerd et.al [62]	✓	✓	✓	✓	✓	✓		✓		✓		✓
Nejc Kozar et.al [63]	✓	✓	✓	✓	✓	✓						✓
F. Allameh et.al [64]	✓	✓	✓	✓	✓	✓		✓				✓
Azadeh Akbari Sene et.al [65]	✓	✓	✓	✓	✓	✓	✓					✓
Sima Ranjbari et.al [66]	✓	✓	✓	✓	✓	✓		✓		✓		✓
Anna Justyna Milewska et.al [67]	✓			✓	✓	✓		✓				✓

TABLE 3: SUMMARY OF APPLICATION OF ML TECHNIQUES FOR PREDICTION OF SUCCESS IN IUI.

Authors	Year of Publication	Number of participants / IUI Cycles	Study Region	AI/ML Algorithms	Accuracy
Michal youngster et.al [59]	2023	2,467 (Cycles)		NGBoost	-
Changbo Jin et.al [60]	2022	25592	Shanghai, China	1) Random forest 2) Entropy-based feature discretization	95%
Sajad Khodabandelu et.al [61]	2022	546	North of Iran	1) Logistic regression 2) Support vector classification 3) Random forest 3) Extreme Gradient Boosting 4) Stacking generalization	75% 80% 84% 89% 88%
Ameneh Mehrjerd et.al [62]	2022	1196	Iran	1) Logistic Regression 2) Random Forest 3) k Nearest Neighbors 4) Support Vector Machine 5) Gradient Naïve Bayes	83% 84% 81% 82% 75%
Nejc Kozar et.al [63]	2021	413 (1029 Cycles)	Slovenia	1) Support Vector Machine 2) Multilayer perceptron 3) General linear model 4) Random forest 5)Partial least squeares 6) SVM Linear	55% 55% 57% 66% 62% 56%
F. Allameh et.al [64]	2021	124 (157 Cycles)	Tehran, Iran	1) J48 2) Bayesian Network 3) Neural Network 4) Support Vector Machine 5) Logistic Regression 6) K-Nearest Neighbors	97% 95% 91% 97% 81% 76%
Azadeh Akbari Sene et.al [65]	2021	380	Tehran, Iran	Three-layer neural network classifier	71.92%
Sima Ranjbari et.al [66]	2021	8,360 (11,255 Cycles)	Iran	1)Random Forest 2) Decision Tree 3) Naïve Bayes 4) ANN 5) Support Vector Machine 6) Extreme Gradient Boosting 7) CNFE-SE	58% 55% 53% 50% 54% 55% 71%
Anna Justyna Milewska et.al [67]	2013	825 (Cycles)	Lakewood, USA	k-means algorithm Kohonen Neural Networks	-

5. Discussions

The follwing observations are outlined from the review:

IUI success rates can exhibit regional disparities. Several factors contribute to this variation, including cultural and socioeconomic factors[68]. Therefore, it's essential to consider these regional differences when assessing the outcomes of IUI and when designing fertility treatment strategies for specific regions. A key observation from the review is that much of the research has focused on specific country, such as Iran, with no evidence of studies on the application of ML approaches for predicting the success of IUI within the framework of the Indian community. Hence tailoring research to the Indian context may ensures more accurate and relevant outcomes.

The emotional factor can significantly influence the success of IUI. Couples undergoing fertility treatments, including IUI, often experience high levels of stress, anxiety, and emotional turmoil [69]. It should be emphasized that studies concerning the success of IUI have often overlooked or inadequately addressed the influence of emotional factors on the outcomes of the procedure. Subsequent research efforts should contemplate this crucial aspect to furnish a comprehensive understanding of the factors influencing IUI success.

The impact of yoga and meditation on the success of IUI is a subject of growing interest within the realm of fertility research. Both yoga and meditation have gained recognition for their potential to positively influence multiple dimensions of reproductive health and emotional well-being, which can, in turn, affect the outcomes of fertility treatments like IUI [70].

This notable gap in the literature underscores the need for more thorough research that specifically examine the interrelation between yoga, meditation, and IUI success. Such research could offer valuable perspectives into the potential benefits of incorporating mind-body practices into fertility treatment protocols and offer a holistic approach to addressing the emotional and physiological aspects of infertility.

Conclusions

In conclusion, this survey on machine learning in forecasting success in intrauterine insemination (IUI) has shed light on the promising advancements and challenges in applying artificial intelligence to reproductive medicine. As the demand for assisted reproductive technologies continues to rise, accurate prediction of IUI success becomes increasingly vital for couples struggling with fertility issues.

The selection and extraction of relevant features are crucial in developing accurate prediction models. Researchers have examined diverse factors like patient characteristics, hormonal profiles, cycle parameters, and sperm analysis results. Integrating additional data sources like emotional factor and yoga and meditation factors holds potential for enhancing prediction models. Implementation of ML techniques for predicting the success of IUI within the Indian population framework, is still a field with unexplored possibilities.

References

[1] N.E.C. Hutcherson, J.B. Harris, L.R. Karaoui, L. Lakdawala, N.M. Lodise, R.H. Stone, V. Vernon, Infertility Management and Pharmacotherapy: What Every Pharmacist Should Know, J. Pharm. Pract. 34 (2021). https://doi.org/10.1177/0897190020930969.

[2] 1 in 6 people globally affected by infertility: WHO, (n.d.). https://www.who.int/news/item/04-04-2023-1-in-6-people-globally-affected-by-infertility (accessed October 5, 2023).

[3] L. V. Farland, S.M. Khan, S.A. Missmer, D. Stern, R. Lopez-Ridaura, J.E. Chavarro, A. Catzin-Kuhlmann, A.P. Sanchez-Serrano, M.S. Rice, M. Lajous, Accessing medical care for infertility: a study of women in Mexico, F S Reports. 4 (2023). https://doi.org/10.1016/j.xfre.2022.11.013.

[4] The Lancet Global Health, Infertility—why the silence?, Lancet Glob. Heal. 10 (2022). https://doi.org/10.1016/S2214-109X(22)00215-7.

[5] Naina Purkayastha, H. Sharma, Prevalence and potential determinants of primary infertility in India: Evidence from Indian demographic health survey, Clin. Epidemiol. Glob. Heal. 9 (2021). https://doi.org/10.1016/j.cegh.2020.08.008.

[6] S.Z. Masoumi, P. Parsa, N. Darvish, S. Mokhtari, M. Yavangi, G. Roshanaei, An epidemiologic survey on the causes of infertility in patients referred to infertility center in Fatemieh Hospital in Hamadan, Iran. J. Reprod. Med. 13 (2015).

[7] P. Deshpande, A. Gupta, Causes and prevalence of factors causing infertility in a public health facility,

J. Hum. Reprod. Sci. 12 (2019). https://doi.org/10.4103/jhrs.JHRS_140_18.

[8] S. Brugo-Olmedo, C. Chillik, S. Kopelman, Definition and causes of infertility, Reprod. Biomed. Online. 2 (2001). https://doi.org/10.1016/S1472-6483(10)62193-1.

[9] N. Kirca, A.S. Celik, Infertile Women's Perceptions of Infertility: A Phenomenological Study Based on Metaphor Analysis, Curr. Women s Heal. Rev. 18 (2021). https://doi.org/10.2174/1573404817666210223162239.

[10] R. Anokye, E. Acheampong, W.K. Mprah, J.O. Ope, T.N. Barivure, Psychosocial effects of infertility among couples attending St. Michael's Hospital, Jachie-Pramso in the Ashanti Region of Ghana, BMC Res. Notes. 10 (2017). https://doi.org/10.1186/s13104-017-3008-8.

[11] L. Schmidt, Social and psychological consequences of infertility and assisted reproduction - What are the research priorities?, Hum. Fertil. 12 (2009). https://doi.org/10.1080/14647270802331487.

[12] M. Jain, M. Singh, Assisted Reproductive Technology (ART) Techniques, 2022.

[13] W. Ombelet, The revival of intrauterine insemination: evidence-based data have changed the picture., Facts, Views Vis. ObGyn. 9 (2017).

[14] S. Jain, Intrauterine Insemination: Current Place in Infertility Management, Eur. Med. J. (2018). https://doi.org/10.33590/emj/10314775.

[15] M. Lee, S. Sechler, A. Mason, A. Amaddio, R. Flyckt, S.T. Kim, PREDICTORS FOR SUCCESS OF INTRAUTERINE INSEMINATION: A RETROSPECTIVE ANALYSIS, Fertil. Steril. 116 (2021). https://doi.org/10.1016/j.fertnstert.2021.05.031.

[16] A. Starosta, C.E. Gordon, M.D. Hornstein, Predictive factors for intrauterine insemination outcomes: a review, Fertil. Res. Pract. 6 (2020). https://doi.org/10.1186/s40738-020-00092-1.

[17] T. Wasilewski, M. Łukaszewicz-Zając, J. Wasilewska, B. Mroczko, Biochemistry of infertility, Clin. Chim. Acta. 508 (2020). https://doi.org/10.1016/j.cca.2020.05.039.

[18] M. Szamatowicz, J. Szamatowicz, Proven and unproven methods for diagnosis and treatment of infertility, Adv. Med. Sci. 65 (2020). https://doi.org/10.1016/j.advms.2019.12.008.

[19] J. Bajwa, U. Munir, A. Nori, B. Williams, Artificial intelligence in healthcare: transforming the practice of medicine, Futur. Healthc. J. 8 (2021). https://doi.org/10.7861/fhj.2021-0095.

[20] M. Javaid, A. Haleem, R. Pratap Singh, R. Suman, S. Rab, Significance of machine learning in healthcare: Features, pillars and applications, Int. J. Intell. Networks. 3 (2022). https://doi.org/10.1016/j.ijin.2022.05.002.

[21] H. Sun, K. Depraetere, L. Meesseman, P.C. Silva, R. Szymanowsky, J. Fliegenschmidt, N. Hulde, V. Von Dossow, M. Vanbiervliet, J. De Baerdemaeker, D.M. Roccaro-Waldmeyer, J. Stieg, M.D. Hidalgo, F.M. Dahlweid, Machine Learning-Based Prediction Models for Different Clinical Risks in Different Hospitals: Evaluation of Live Performance, J. Med. Internet Res. 24 (2022). https://doi.org/10.2196/34295.

[22] S. Dara, S. Dhamercherla, S.S. Jadav, C.M. Babu, M.J. Ahsan, Machine Learning in Drug Discovery: A Review, Artif. Intell. Rev. 55 (2022). https://doi.org/10.1007/s10462-021-10058-4.

[23] M. Toma, O.C. Wei, Predictive Modeling in Medicine, Encyclopedia. 3 (2023). https://doi.org/10.3390/encyclopedia3020042.

[24] S. Garg, S.R. Bhagyashree, Detection and Classification of Tumors Using Medical Imaging Techniques: A Survey, in: Lect. Notes Data Eng. Commun. Technol., 2020. https://doi.org/10.1007/978-3-030-28364-3_35.

[25] S.I.R. Bhagyashree, K. Nagaraj, M. Prince, C.H.D. Fall, M. Krishna, Diagnosis of Dementia by Machine learning methods in Epidemiological studies: a pilot exploratory study from south India, Soc. Psychiatry Psychiatr. Epidemiol. 53 (2018). https://doi.org/10.1007/s00127-017-1410-0.

[26] M.E. Graham, A. Jelin, A.H. Hoon, A.M. Wilms Floet, E. Levey, E.M. Graham, Assisted reproductive technology: Short- and long-term outcomes, Dev. Med. Child Neurol. 65 (2023). https://doi.org/10.1111/dmcn.15332.

[27] A.B. Alias, H.Y. Huang, D.J. Yao, A review on microfluidics: An aid to assisted reproductive technology, Molecules. 26 (2021). https://doi.org/10.3390/molecules26144354.

[28] M. Latifi, L. Allahbakhshian, F. Eini, N.A. Karami, M.N. Al-Suqri, Health information needs of

couples undergoing assisted reproductive techniques, Iran. J. Nurs. Midwifery Res. 27 (2022). https://doi.org/10.4103/ijnmr.ijnmr_328_21.
[29] N. Zaninovic, Z. Rosenwaks, Artificial intelligence in human in vitro fertilization and embryology, Fertil. Steril. 114 (2020). https://doi.org/10.1016/j.fertnstert.2020.09.157.
[30] J.F. Hasler, J.P. Barfield, In Vitro Fertilization, in: Bov. Reprod., 2021. https://doi.org/10.1002/9781119602484.ch89.
[31] S. Ashibe, R. Miyamoto, Y. Kato, Y. Nagao, Detrimental effects of oxidative stress in bovine oocytes during intracytoplasmic sperm injection (ICSI), Theriogenology. 133 (2019). https://doi.org/10.1016/j.theriogenology.2019.04.012.
[32] M. Giacobbe, M. Conatti, A. Gomes, T.C.S. Bonetti, P.A.A. Monteleone, Effectivity of conventional in vitro fertilization (IVF) and intracytoplasmic sperm injection (ICSI) when male factor is absent: A perspective point of view, J. Bras. Reprod. Assist. 26 (2022). https://doi.org/10.5935/1518-0557.20210031.
[33] Chapter 18: Gamete intrafallopian transfer, Fertil. Steril. 87 (2007). https://doi.org/10.1016/j.fertnstert.2007.01.083.
[34] I. Szmelskyj, L. Aquilina, A.O. Szmelskyj, The fundamentals of ART, Acupunct. IVF Assist. Reprod. (2015) 143–159. https://doi.org/10.1016/B978-0-7020-5010-7.00006-0.
[35] C. Ranoux, M. Seibel, H. Foulot, J.B. Dubuisson, F.X. Aubriot, D. Rambaudb, Lessons Learned from IVC (Intra-Vaginal Culture), in: Adv. Assist. Reprod. Technol., 1990. https://doi.org/10.1007/978-1-4613-0645-0_30.
[36] G.N. Allahbadia, Intrauterine Insemination: Fundamentals Revisited, J. Obstet. Gynecol. India. 67 (2017). https://doi.org/10.1007/s13224-017-1060-x.
[37] F.R. Parikh, A.S. Athalye, N.J. Naik, D.J. Naik, R.R. Sanap, P.F. Madon, Preimplantation genetic testing: Its evolution, where are we today?, J. Hum. Reprod. Sci. 11 (2018). https://doi.org/10.4103/jhrs.JHRS_132_18.
[38] J. Gunnarsson Payne, E. Korolczuk, S. Mezinska, Surrogacy relationships: a critical interpretative review, Ups. J. Med. Sci. 125 (2020). https://doi.org/10.1080/03009734.2020.1725935.
[39] C.B. Nesbit, M. Blanchette-Porter, N. Esfandiari, Ovulation induction and intrauterine insemination in women of advanced reproductive age: a systematic review of the literature, J. Assist. Reprod. Genet. 39 (2022). https://doi.org/10.1007/s10815-022-02551-8.
[40] D. Whaley, K. Damyar, R.P. Witek, A. Mendoza, M. Alexander, J.R.T. Lakey, Cryopreservation: An Overview of Principles and Cell-Specific Considerations, Cell Transplant. 30 (2021). https://doi.org/10.1177/0963689721999617.
[41] M. Okhovati, M. Zare, F. Zare, M.S. Bazrafshan, A. Bazrafshan, Trends in Global Assisted Reproductive Technologies Research: a Scientometri[1] M. Okhovati, M. Zare, F. Zare, M. S. Bazrafshan, and A. Bazrafshan, “Trends in Global Assisted Reproductive Technologies Research: a Scientometrics study,” Electron. physician, Electron. Physician. 7 (2015). https://doi.org/10.19082/1597.
[42] D. Diego, A. Medline, L.M. Shandley, J.F. Kawwass, H.S. Hipp, Donor sperm recipients: fertility treatments, trends, and pregnancy outcomes, J. Assist. Reprod. Genet. 39 (2022). https://doi.org/10.1007/s10815-022-02616-8.
[43] W. Ombelet, Evidence-based recommendations for IUI in daily practice, Middle East Fertil. Soc. J. 18 (2013). https://doi.org/10.1016/j.mefs.2013.01.001.
[44] R. Nauber, S.R. Goudu, M. Goeckenjan, M. Bornhäuser, C. Ribeiro, M. Medina-Sánchez, Medical microrobots in reproductive medicine from the bench to the clinic, Nat. Commun. 14 (2023). https://doi.org/10.1038/s41467-023-36215-7.
[45] R. Homburg, IUI is a better alternative than IVF as the first-line treatment of unexplained infertility., Reprod. Biomed. Online. 45 (2022) 1–3. https://doi.org/10.1016/j.rbmo.2021.12.015.
[46] Intrauterine Insemination (IUI) vs IVF, (n.d.). https://www.news-medical.net/health/Intrauterine-Insemination-(IUI)-vs-IVF.aspx (accessed October 5, 2023).
[47] Different Infertility Treatment Procedure and Their Cost In India, (n.d.). https://subhag.in/different-

infertility-treatments-and-how-does-iui-work/ (accessed October 5, 2023).
[48] G. Bahadur, B. Woodward, M. Carr, S. Acharya, A. Muneer, R. Homburg, Iui needs fairer appraisal to improve patient and stakeholder choices, J. Bras. Reprod. Assist. 25 (2021). https://doi.org/10.5935/1518-0557.20200066.
[49] A.M. Abdelkader, J. Yeh, The Potential Use of Intrauterine Insemination as a Basic Option for Infertility: A Review for Technology-Limited Medical Settings, Obstet. Gynecol. Int. 2009 (2009). https://doi.org/10.1155/2009/584837.
[50] P. Saxena, A. Mishra, IUI: Optimizing results, minimizing complications, Fertil. Sci. Res. 8 (2021). https://doi.org/10.4103/2394-4285.319901.
[51] A.J. Goverde, J. McDonnell, J.P.W. Vermeiden, R. Schats, F.F.H. Rutten, J. Schoemaker, Intrauterine insemination or in-vitro fertilisation in idiopathic subfertility and male subfertility: A randomised trial and cost-effectiveness analysis, Lancet. 355 (2000). https://doi.org/10.1016/S0140-6736(99)04002-7.
[52] A.J. Ainsworth, E.P. Barnard, S.C. Baumgarten, A.L. Weaver, Z. Khan, Intrauterine insemination cycles: prediction of success and thresholds for poor prognosis and futile care, J. Assist. Reprod. Genet. 37 (2020). https://doi.org/10.1007/s10815-020-01918-z.
[53] A.L. Zippl, A. Wachter, P. Rockenschaub, B. Toth, B. Seeber, Predicting success of intrauterine insemination using a clinically based scoring system, Arch. Gynecol. Obstet. 306 (2022). https://doi.org/10.1007/s00404-022-06758-z.
[54] A. Huniadi, E. Bimbo-Szuhai, M. Botea, I. Zaha, C. Beiusanu, A. Pallag, L. Stefan, A. Bodog, M. Șandor, C. Grierosu, Fertility Predictors in Intrauterine Insemination (IUI), J. Pers. Med. 13 (2023). https://doi.org/10.3390/jpm13030395.
[55] M. Sava, E. Tamburac, B. Karadag, A. Uysal, Pregnancy rates after ovulation induction and affecting factors in unexplained infertile and male factor infertility, Int. J. Clin. Obstet. Gynaecol. 6 (2022) 80–86. https://doi.org/10.33545/gynae.2022.v6.i1b.1116.
[56] A.P. Patel, M.S. Patel, S.R. Shah, S.K. Jani, Predictive factors for pregnancy after intrauterine insemination: A retrospective study of factors affecting outcome, J. SAFOG. 8 (2016). https://doi.org/10.5005/jp-journals-10006-1404.
[57] L.H. Goetz, N.J. Schork, Personalized medicine: motivation, challenges, and progress, Fertil. Steril. 109 (2018). https://doi.org/10.1016/j.fertnstert.2018.05.006.
[58] J. Stanhiser, A.Z. Steiner, Psychosocial Aspects of Fertility and Assisted Reproductive Technology, Obstet. Gynecol. Clin. North Am. 45 (2018). https://doi.org/10.1016/j.ogc.2018.04.006.
[59] M. Youngster, A. Luz, M. Baum, R. Hourvitz, S. Reuvenny, E. Maman, A. Hourvitz, Artificial intelligence in the service of intrauterine insemination and timed intercourse in spontaneous cycles., Fertil. Steril. (2023). https://doi.org/10.1016/j.fertnstert.2023.07.008.
[60] C. Jin, J. Zong, S. Xue, Development of a Diagnosis Grading System for Patients Undergoing Intrauterine Inseminations: A Machine-learning Perspective, MedRxiv. (2022) 2022.07.18.22277308. https://doi.org/10.1101/2022.07.18.22277308.
[61] S. Khodabandelu, Z. Basirat, S. Khaleghi, S. Khafri, H. Montazery Kordy, M. Golsorkhtabaramiri, Developing machine learning-based models to predict intrauterine insemination (IUI) success by address modeling challenges in imbalanced data and providing modification solutions for them, BMC Med. Inform. Decis. Mak. 22 (2022). https://doi.org/10.1186/s12911-022-01974-8.
[62] A. Mehrjerd, H. Rezaei, S. Eslami, M.B. Ratna, N. Khadem Ghaebi, Internal validation and comparison of predictive models to determine success rate of infertility treatments: a retrospective study of 2485 cycles, Sci. Rep. 12 (2022). https://doi.org/10.1038/s41598-022-10902-9.
[63] N. Kozar, V. Kovač, M. Reljič, Can methods of artificial intelligence aid in optimizing patient selection in patients undergoing intrauterine inseminations?, J. Assist. Reprod. Genet. 38 (2021). https://doi.org/10.1007/s10815-021-02224-y.
[64] F. Allameh, M. Fallah-Karkan, S.Z. Modarres, A.R. Abedi, M.J. Eslami, M.R. Hajian, M. Dadpour, L. Zareian, Machine Learning Approaches to predict Intra-Uterine Insemination Success Rate-Application of Artificial Intelligence in Infertility, Men's Heal. J. 5 (2021).
[65] A.A. Sene, Z. Zandieh, M. Soflaei, H.M. Torshizi, K. Sheibani, Using artificial intelligence to predict

the intrauterine insemination success rate among infertile couples, Middle East Fertil. Soc. J. 26 (2021). https://doi.org/10.1186/s43043-021-00091-2.

[66] S. Ranjbari, T. Khatibi, A. Vosough Dizaji, H. Sajadi, M. Totonchi, F. Ghaffari, CNFE-SE: a novel approach combining complex network-based feature engineering and stacked ensemble to predict the success of intrauterine insemination and ranking the features, BMC Med. Inform. Decis. Mak. 21 (2021). https://doi.org/10.1186/s12911-020-01362-0.

[67] A.J. Milewska, D. Jankowska, U. Cwalina, T. Wiesak, D. Citko, A. Morgan, R. Milewski, Analyzing outcomes of intrauterine insemination treatment by application of cluster analysis or Kohonen neural networks, Stud. Logic, Gramm. Rhetor. 35 (2013). https://doi.org/10.2478/slgr-2013-0041.

[68] L.T.B. Craig, E.A. Weedin, W.D. Walker, A.E. Janitz, K.R. Hansen, J.D. Peck, Racial and Ethnic Differences in Pregnancy Rates Following Intrauterine Insemination with a Focus on American Indians, J. Racial Ethn. Heal. Disparities. 5 (2018). https://doi.org/10.1007/s40615-017-0456-8.

[69] H. Zhu, S. Xu, M. Wang, Y. Shang, C. Wei, J. Fu, Effect of hope therapy on fertility stress and pregnancy rate in infertile patients undergoing intrauterine insemination., Am. J. Transl. Res. 14 (2022).

[70] S. Darbandi, M. Darbandi, H.R.K. Khorshid, M.R. Sadeghi, Yoga can improve assisted reproduction technology outcomes in couples with infertility, Altern. Ther. Health Med. 24 (2018).