RESEARCH PAPER

Application of Artificial Intelligence in Assisted Reproductive Technologies in India: A Critical Analysis

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ABSTRACT

The Application of Artificial Intelligence embraces enormous power to influence the healthcare sector positively, especially in Assisted Reproductive Technologies worldwide. The adoption of AI in the ART meets the broader objectives of the UNSDGs, particularly Goal 3 (which ensures Good Health and Well-Being), Goal 5 (achieve Gender Equality), and Goal 9 (promote sustainable Industry, Innovation, and Infrastructure) by promoting reproductive health, empowering individuals' reproductive choices, and encouraging technological innovation in the healthcare system in India. However, it has become a concern for law and society, including privacy, consent, and equal access for all. This study aims to examine the growing use of AI in Assisted Reproductive Technologies as an emerging development in reproductive healthcare in India, and examines the existing legal frameworks for ART, as well as the applications of AI in reproductive healthcare in India. The Study follows the doctrinal and analytical research methodology and is constructed on sources of primary and secondary data. The study shows that AI can improve procedures related to ARTs. AI technology is used to advance embryo selection, sperm quality, and the success rate of IVF procedures. This improves accuracy, reduces human error, and increases the success of a pregnancy. However, data privacy, ethical issues, and a lack of clear regulatory guidelines on AI are major issues. AI is playing an important role in transforming the reproductive healthcare sector in India by improving reproductive health, empowering reproductive choices of individuals, and enhancing technological innovations in the country's healthcare system. However, the speedy development of Artificial Intelligence in the field requires effective legal and ethical frameworks to address issues of privacy, transparency, and ethics.

Keywords: Artificial Intelligence, Healthcare, Assisted Reproductive Technology, Data Privacy, Reproductive Law

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1. INTRODUCTION

Background

AI is the potential of machines or CPU systems to perform any tasks that require 'human intelligence.' 'AI' is the field that studies how computers can learn to solve problems through symbolic language [1]. It includes the processes of learning from data, identifying patterns, making judgments, and problem resolution. Data-driven algorithms, deep learning, and data evaluation are part of Artificial Intelligence technologies. These technologies are being utilised across multiple fields, including Education, Agriculture, Finance, Transportation, Manufacturing, Cybersecurity, and Medicine. AI has the capability to make healthcare more modernised, efficient, and reachable through better treatments, diagnoses, and overall efficiency; thus, providing an optimistic outlook on the future of the healthcare system in the coming years [2]. Artificial intelligence has the capability of assisting physicians with analysing large amounts of medical data, thus improving diagnoses, predicting the outcomes of treatments, and creating a more efficient delivery of healthcare services. AI-driven applications in areas such as data analysis, medical imaging, disease detection, and precision medicine have greatly improved the efficiency and accuracy of healthcare systems [3]. Many researchers believe artificial intelligence can accomplish and possibly outperform humans in critical healthcare tasks such as detecting diseases and analysing medical data. In reproductive health care, artificial intelligence will aid physicians in selecting embryos, evaluating sperm quality, and forecasting treatment success rates.

Reproductive Technology is a method of helping couples and individuals who are unable to conceive naturally, and also for those planning to conceive at a later time. All techniques used to treat infertility where there is assistance by both egg/embryos are called ARTs [4]. Examples of these types of treatments include IVF, using donor eggs/sperm, and surrogacy. Other examples of ARTs include manipulating eggs, sperm, or embryos separate of the physique to enhance prenatal period possibilities. ART is currently becoming one of the most popular options for people experiencing difficulties conceiving, for older adults wishing to delay having children (late pregnancy), and for couples concerned with passing on hereditary defects. It provides them with a fair opportunity to have a family when health or biological issues create barriers. People with infertility, couples who want to postpone parenthood, and couples with genetic concerns opting for ART is a judicious choice.

In the period of quick technological innovations, AI-based systems offer a promising new possibility for improving fertility treatment technologies, making the development more effective and successful. The adoption of AI in the healthcare sector, especially in Assisted Reproductive Technology, can enhance embryo selection, diagnostic accuracy, treatment efficiency, and overall success rates of fertility treatments. It is increasingly integrated into medical practices, including assisted reproductive technology, to enhance diagnostic precision and treatment efficacy [5]. This integration of AI and ART has strengthened the probability of success rate of fertility treatments and brought a new hope to many couples. AI in ART offers numerous advantages and enhances the ART outcomes by decreasing interobserver variability, adjusting medicine dosages during oocyte retrieval, and hence reducing antagonistic properties such as hyperstimulation, diminishing one-to-one medical contacts, improving productivity of healthcare providers and patients, better sperm selection samples, and oocyte quality assessment and embryo selection [6].

Integration of AI in ART has increased the success rates of fertility treatment procedures, thus making reproductive healthcare more efficient and widely accessible. This advancement also complements the United Nations Sustainable Development Goals, particularly Sustainable Development Goal 3, which aims to certify hale and hearty lives and encourage well-being for all at all ages. AI-supported ART can contribute to sustainable healthcare systems and better health outcomes by improving reproductive healthcare services. Raises serious ethical, legislative issues, and social impact concerns regarding privacy, informed consent, and equal access for all. The application of AI in assisted reproduction technology is growing at a fast pace in India; however, the legal structure is outdated. Therefore, the necessity of updating and continuously improving the legal framework is emphasised.

India is now one of the major destinations for medical tourism in terms of reproductive medicine because of its relatively low costs and the most recent medical technologies. The Indian Government has implemented regulatory frameworks on the legal side, such as the ART Regulation and the Surrogacy Regulation Act, to provide regulations to fertility clinics, to make sure that fertility clinics are practising ethically, and to provide protections for future parents, donors, and surrogate mothers.

The ART Regulation Act, 2021, provided regulation of fertility clinics and ART services, along with providing rights to patients, donors, and children conceived through these methods.

The Legislative regulation of ART services provides protection for reproductive autonomy while providing ethical medical practice. The Right to Life and Personal Liberty, as stated in Article 21 of the Constitution of India, protects reproductive rights. In Suchita Srivastava v. Chandigarh Administration [7]. In this case, the Supreme Court of India emphasised the fundamental right of women for reproductive autonomy. This also includes the right to carry a pregnancy until birth, to give birth, and to raise children. The court also ruled that this right is a part of a woman's rights to privacy, dignity, and human integrity.

The purpose of the legislation is to ensure ART providers follow ethical, responsible, and transparent ART practices. Government of India, 2021 states under

section 2(a) of the Assisted Reproductive Technology (Regulation) Act, 2021, assisted reproductive technology includes, " all techniques that attempt to obtain a pregnancy by handling the sperm or the oocyte outside the human body and transferring the gamete or the embryo into the reproductive system of a woman [8]."

Statement of Problem

The application of AI in ART is a remarkable progression in reproductive health care in India. However, AI-based applications like improved embryonic screening, fertility prediction, and IVF optimisation improve clinical efficiency and outcomes. Nevertheless, the progress of AI applications in ART has evolved at a much quicker rate than the evolution of laws and regulations governing ART in India. Currently, laws govern ART procedures. However, laws regulating potential problems related to the use of AI-based technologies in ART's do not exist. Therefore, no legal framework exists for regulation on how AI-based technologies can be used in ART. Thus, numerous issues arise as to whether patients' rights will be protected, whether they will be able to provide informed consent, and how their sensitive reproductive information could be misused. It follows that there is an urgent necessity to study the relationship between AI and ART in the context of Indian laws.

Research Objectives

The objectives of this study are:

To understand the increased application of artificial intelligence (AI) in assisted reproduction technologies in India.

To evaluate the present legal and regulatory systems for assisted reproductive technology, as well as to study how AI is being applied in reproductive health care in India.

To find out about some of the privacy, ethical, and legal issues that are associated with using artificial intelligence in reproductive health care.

Significance of the Study

This study is significant as it examines the relatively new field of AI in reproductive medicine and healthcare, which is not widely explored in India. This is important because the study presents an understanding of how AI could reshape the ART procedures and highlights the challenges. The research is important for policymakers, legal scholars, healthcare professionals, and researchers as it draws attention towards the need for a sound regulatory framework that promotes ethical use of AI in reproductive services, safeguards the patient's rights, and upholds accountability. In addition, it helps create a balanced approach to innovations in reproduction.

2. SYSTEMATIC LITERATURE REVIEW

Artificial Intelligence in Healthcare

With rapid advancement in technology around the globe, Artificial Intelligence (AI), as a major development, has evolved rapidly. "AI refers to the science and engineering of creating intelligent machines that follow certain rules based on algorithms to imitate the way humans think — through learning and problem solving [9]." Already, artificial intelligence plays a significant part in medical evaluation and medical care, in drug discovery, studying diseases, reacting to public health emergencies, and managing health systems. "The future of healthcare is digital, and we must do what we can to promote universal access to these innovations and prevent them from becoming another driver for inequity [10]." Machine Intelligence plays an essential part in Reproductive Technology and supports a variety of aspects of healthcare. AI-driven methods like selecting embryos, analysing sperm, and predictive modelling may enhance the efficiency and success rates of ART processes. Techniques utilising artificial intelligence may be applied in reproductive healthcare to increase the selection and prediction of sperm cells, oocytes, and embryos, as well as to develop better predictive models for 'in vitro fertilisation [11].' Intelligence systems help doctors make stronger treatment plans, lower the risk of errors made by humans, and optimize treatment results. Using AI allows for a large amount of data to be studied to determine which embryo will work best. AI evaluates the quality of sperm and determines how much and what type of sperm should be evaluated.

Machine learning uses large amounts of data, including clinical information, lab test results, and imaging data, to find patterns to assist with diagnosis and treatment planning. "Machine learning is a branch of Artificial Intelligence that utilizes large datasets and identifies interaction patterns among variables [12]." Time-lapse cameras produce video footage of embryos, which can then be analysed using AI-powered image analysis software. Machine learning algorithms evaluate morphological characteristics and developmental patterns to estimate embryo viability [13]. There are three classifications of Machine Learning: supervised learning — which uses labelled data — for example, labelled X-ray images of known tumours to find unknown tumours in other images; unsupervised learning — which seeks to draw out knowledge from unlabelled data — for example, grouping patients who exhibit similar symptoms to find a common cause, and reinforcement learning (RL) [12]. AI applications can greatly aid in streamlining workflow issues related to administration and the collection and analysis of data, but must be carefully implemented to avoid dehumanising the clinician/patient interaction and ensure that the use of technology does not diminish the clinical relationship [14].

Deep Learning (DL) is one of several types of machine learning that utilises computer learning to analyse artificial neural networks. DL is currently being utilised in healthcare systems. There is a significant difference between deep learning and traditional machine learning. Deep learning performs substantially better than traditional machine learning techniques when performing in medical image analysis [15]. There are many beneficial traits associated with deep neural networks in healthcare, such as superior performance over traditional methods; end-to-end

learning schemes that allow integrated feature learning; the ability to analyse multi-modal complex data, and so on [16]. Deep Learning (DL) is now being employed in IVF laboratories to assess the quality and quantity of oocyte competence. The assessments provide unbiased and dependable evaluations of meiotic stages critical for successful fertilisation and subsequent embryo development [17]. Technologies employing DL can measure oocyte quality, which could lead to more accurate and efficient assessments via objective measurements and outcome-based predictive modelling [18].

Artificial Intelligence (AI) could improve and make ART technologies in India more accurate, reduce their cost, and expand them more effectively through a digital platform. For example, AI tools can be used for online consultations, online monitoring of a patient's progress, and examination of medical data. These can help reduce the need for regular hospital visits, making treatment easier and less expensive, especially for people living in remote areas. But the current scenario is different in India. Most of the advanced AI technology in ART needs a highly developed infrastructure that includes powerful computers, software tools, internet connectivity, and healthcare experts, data scientists who are professionally skilled. These things are easily available in well-funded, private fertility clinics situated in urban centres. On the other hand, people from small cities and rural areas are deprived of these treatments as their clinics and government hospitals often lack even basic infrastructure.

There is a shortage of trained medical experts familiar with using AI tools. “All health workers in these areas will have to be trained and retrained in the use of AI to support and facilitate their tasks [10].” Internet connectivity is poor, and funding for advanced systems is limited. Even if the cost of AI tools could be reduced, the initial investment is high, which makes them inaccessible for low-income or marginalised communities [10].

The widening gap is an indicator as to why policy must focus on improving the quality of digital infrastructure in rural settings, supporting AI-based tools for government agencies and lower cost clinics, providing medical professionals with education/training opportunities in using AI, and making sure everyone – regardless of their financial situation, where they live or who they are – has equal opportunity to utilise AI in ART.

Tedros Adhanom Ghebreyesus stated, "The future of healthcare will be digital," and he believes we should work together to make it accessible to everyone, rather than allowing it to become one of many contributing factors to further divide us.

Assisted Reproductive Technologies (ART) in India

Human reproduction is considered a significant area of life for humans. Though many people are blessed with the ability to conceive naturally, many have difficulties due to certain medical or biological reasons. For these people, Assisted Reproductive Technologies provide the necessary medical solution for them to become parents. Assisted Reproductive Technologies are blessings for those who are facing problems in conceiving naturally or planning a later pregnancy. Assisted Reproductive Technologies refer to medical techniques used to help individuals or couples who face difficulties in conceiving naturally. The reproductive techniques are treatments of infertility in which handling of both the egg and the embryo is done. The treatment includes IVF, using donated eggs or sperm, and surrogacy. handling sperm, eggs, or embryos outside the body to make pregnancy more likely are the methods of this treatment. The Government of India has also introduced legal frameworks to regulate fertility clinics and safeguard ethical practices in reproductive medicine. The Act provides a legal definition of assisted reproductive technology under section 2(a): “ART encompasses the different forms and terminology related to methods aimed at achieving a pregnancy via sperm and/or the oocyte outside the human body, followed by the introduction of one or both of these into a woman’s reproductive tract [19].” Recently, there has been an increase in the popularity of ART for those who experience difficulties in producing offspring; for those desiring to postpone parenthood (i.e., late pregnancy); and for purposes of assessing heritable transmissions of genetic diseases. ART allows individuals to create families when either a health condition or another biological issue prevents them from doing so. ART also provides options for creating families where medical/biological barriers exist. Since the birth of the first “test-tube” baby (the term is often applied loosely, but technically refers to a child conceived through “In Vitro Fertilisation”) in 1978, ART has undergone many changes and improvements. The advances in science and technology over the years have transformed the field of Reproductive Medicine to provide new, innovative ways to solve reproductive problems and expand the possibilities for becoming a parent. The types of ART used to assist infertile couples include: IVF, ICSI, GIFT, Sperm/Egg Donation, Eggs/Freezing Embryos, Surrogacy

Legal Recognition of Assisted Reproductive Technology (ART) in India

There is a law regarding Assisted Reproduction Technologies and Surrogacy in India. The laws are specifically designed to shield the rights of those who use these services, their donors, surrogate mothers, as well as the ethical practices of those who provide them. To do this, there have been two pieces of legislation passed by the Government of India: “The Assisted Reproductive Technology (Regulation) Act, 2021 [19]” which will control and administer the ART industry in India. This includes fertility clinics, ART banks, and the overall practice of assisted reproduction in India. “The Surrogacy (Regulation) Act, 2021 [8]” will also regulate the practice of surrogacy in India, and it will only allow for non-commercial surrogacy. Both Acts are intended to provide transparency and

accountability to this emerging area of reproductive medicine in India.

Applications of Artificial Intelligence in Assisted Reproductive Technologies (ART)

AI is being used in numerous applications in the medical field. In ART, AI is increasingly used to expand the interpretation of medical imaging results, clinical decision-making, reduce human error, and increase the success rates of fertility treatments. It is used to improve the discovery of drugs, the monitoring of patients, medical images, and biological parameters to assist embryologists and fertility specialists in selecting the most viable embryos, evaluating sperm quality, improving treatment protocols, and identifying genetic risks. AI became an essential tool in fertility treatment, improving, in cooperation, the success of treatments and supporting the clinical decisions of healthcare professionals [17]. One of the most important uses of AI in ART is the selection of better embryos. AI enhances embryo assessment by examining the shape and timing of embryo development and genetic information to select embryos for a successful pregnancy [20]. Artificial intelligence's unbiased analysis helps reduce the chance of human error in embryo selection and improves the chances of successful implantation [21]. Currently, AI algorithms for selecting better embryos for transfer normally depend on several parameters, including shape movement, hereditary data, cycle information, and image-based morphology [22]. Consequently, the selection of embryos with the help of AI can result in higher success rates in implantation since the best embryos will be selected for the purpose. The artificial intelligence support improves embryo selection rates for effective implantation amongst embryologists, compared to the assessment by embryologists alone [23]. Another emerging application of AI is sperm analysis. The use of AI in sperm examination represents a new advancement in ART. AI techniques can help in predicting the semen quality by analysing ecological factors and routine effects on sperm quality measures, thereby improving the accuracy of sperm analysis [24]. It is used in the analysis of semen to improve the quality of sperm. By reducing human error, AI enhances sperm selection, provides fair, data-based evaluations of sperm health, and advances treatment outcomes [25]. AI is also used to evaluate sperm characteristics and the genetic integrity of sperm, which is important for understanding male fertility issues and improving treatment plans. It also shows potential for use in DNA fragmentation analysis to categorize viable sperm with intact genetic material [26]. In assisted reproductive technologies (ART), ovarian stimulation is an important step that involves numerous decisions about medication procedures, doses, and timing, which can differ for each patient's unique profile [27]. AI can assist fertility doctors by suggesting individualised treatment plans, optimising the number of eggs collected, and improving treatment outcomes by examining big datasets from previous IVF cycles. Furthermore, to improve the accuracy and efficiency of embryos in genetic screening, Artificial Intelligence is playing an important role.

Apart from the adoption of AI in ART, it is also playing an important part in achieving other global development goals. According to the United Nations Global Compact (2025), Artificial Intelligence is not only a technological breakthrough, but also a powerful tool that can accelerate progress in achieving all 17 SDGs. In the healthcare sector, AI directly contributes to achieving Sustainable Development Goal 3, which is focused on improving healthcare services and reducing health inequalities.

Legal and Ethical Issues of Artificial Intelligence in Assisted Reproductive Technologies in India

The "Assisted Reproductive Technology (Regulation) Act, 2021" was passed to legalise and manage the ART industry in India. The Act regulates the ART banks, prevents misuse, ensures the safe use of technologies such as IVF, ICSI, and gamete donation, and protects the rights of both patients and donors. This Act constitutes the National and State boards to guarantee the right regulation, supervision, and ethical implementation of assisted reproductive technologies across the country. The Act mandates compulsory registration of all ART clinics and banks with national and state regulatory boards, and sets standards regarding infrastructure, staffing, and record-keeping. Clinics are not allowed to conduct any type of sex selection, commercial exploitation, or the selling or transferring of embryos and gametes is completely banned. In today's time, where technologies like AI have already made their way into Reproductive Technologies, the ART Act fails to mention AI in any form. There is no discussion, provision, or regulation in the Act related to AI. There is also no dedicated board or authority to monitor or regulate the practice of AI in ART procedures. This is a major problem as AI is currently being used in Indian fertility clinics in different procedures. Despite its growing role, the Act remains silent on the regulation of such technologies, which is an important legal and ethical gap in the current framework. Similarly, the Surrogacy (Regulation) Act, 2021, was established by the government. It establishes the national and state boards to regulate and supervise surrogacy procedures, registration of clinics, and grievance redressal. The Act establishes national and state boards to regulate and supervise surrogacy procedures, registration of clinics, and grievance redressal. AI is increasingly being used for tasks such as embryo selection, gamete analysis, genetic screening, and surrogate-matching algorithms. Like the "Assisted Reproductive Technology (Regulation) Act, 2021," which does not provide any establishment for the application of AI in reproductive procedures, the Surrogacy Regulation Act, 2021, also does not have any provision regarding the usage of AI in surrogacy. Today, AI is being utilised for various applications like embryo selection, gamete analysis, genetic testing, and surrogate matching algorithms. It can be concluded from this fact that the lack of

provisions about AI in both the legislation demonstrates a serious deficiency in India's regulatory system concerning the application of AI in ART.

3. RESEARCH METHODOLOGY

Research Design

A doctrinal and analytical approach is followed to assess the title role of Artificial Intelligence in Assisted Reproductive Technologies (ART) under the Indian legal and health care systems. This study will focus on analysing secondary resources, i.e., statutes, Government Policies, Literature on AI in ART, Scholarly writings, etc.

Sources of Data

Study based on secondary source of data collection, including Statutes, Reports of Govt., Policy Documents, Legislation, Books on Reproductive Health & AI in Healthcare & Articles/ Journals on Research.

Scope and Limitations of the Study

This study deals with the application of AI in ART in India. It provides an overview of legal and regulatory frameworks in respect of ART & AI and an analysis of legal, ethical, and privacy issues associated with AI in reproductive healthcare.

The study is limited to Secondary Resources; hence, it might not reflect real Clinical Practices. The research is limited to the Indian context and does not broadly compare international frameworks.

4. CONCLUSION AND SUGGESTIONS

Summary of Key Findings

Assisted Reproductive Technology (ART) is a blessing for couples and individuals who are facing the problem of infertility. On the other hand, AI can be looked upon as an advanced form of this technology. With the help of AI in ART, the treatments become more accurate, efficient, and successful in assisting people with their infertility problems. AI may increase the chances of success rates of fertility treatments, while human error and treatment costs may decrease. However, in India, the growth of AI technologies is very rapid, but no legislation or regulatory body is overseeing this sector. There is no reference to the use of AI in either the "Assisted Reproductive Technology (Regulation) Act, 2021" nor in the "The Surrogacy (Regulation) Act, 2021". Due to a lack of legal recognition and a regulatory gap, there have been some gaps in governance, particularly when AI tools are already being used in many private fertility clinics in India. In the absence of legal recognition or guidelines, the risk of misuse, unethical practices, violations of data privacy, and unfair access to advanced treatments increases. Misuse of patient information due to the lack of appropriate data protection, as well as breach of privacy, could lead to emotional harm, even genetic discrimination. Therefore, this includes not only recognising AI as an integral element of contemporary ART practices but also developing legally-binding guidelines that clearly define how it can be used, monitored, and held accountable. Thus, ultimately, whether AI will positively impact the reproductive health care system in India will depend upon strong legislative support, regulated ethics, equitably available infrastructure, and a high degree of public confidence.

Suggestions

The Assisted Reproductive Technology (Regulation) Act, 2021, and the Surrogacy (Regulation) Act, 2021, must each be amended to include provisions regarding the utilisation of artificial intelligence. Data protection legislation needs to be developed to protect highly personal reproductive and genetic information.

A national or state-based oversight board needs to be created to oversee the use of AI in reproductive health care services.

A greater awareness of AI and ART technology needs to be fostered among rural populations and lower socioeconomic communities to ensure they have equal access to cutting-edge reproductive medical technologies.

Training programs should be introduced for medical professionals to effectively use AI in reproductive healthcare and to increase their proficiency.

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