Review Article

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Revolutionizing Reproductive Health: A Narrative Review on the Role of AI in Transforming Infertility Care in Pakistan

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ABSTRACT

The integration of artificial intelligence (AI) into infertility care is transforming the field of gynecology, providing new solutions that improve diagnosis and treatment. AI technology is being used to increase the accuracy of fertility tests, personalized treatment plans, and to more accurately predict outcomes. Intelligent models can measure important information such as hormone levels and ultrasound scans. This review examines how AI enhances patient treatment by reducing diagnostic time and enhancing patient care and decision-making efficiency. Since there is a disconnect between male infertility, taken care of by urologists, and female infertility managed by gynecologists, we want to bridge this gap through the use of AI in treatment. This article looks at the institutional and cultural constraints that frequently keep husbands from going to infertility consultations with their wives. Infertility is typically viewed as a woman's problem in our conservative settings, which means that she must endure years of treatment. Women continue to receive hormonal treatments until the male element is brought to light because there is an unwillingness on the part of men to get tested. AI can be used to develop treatment regimens that equally incorporate both parties. Current applications, challenges, and future directions of AI in Pakistan and low-resource settings highlight promising opportunities for alleviating the disparity between male and female infertility care. This descriptive review aims to explore the application of AI to improve medical care, provide personalized counseling, and increase diagnostic accuracy. However, the use of AI in infertility care also raises ethical, regulatory, and accessibility issues that must be addressed to ensure that AI is responsible and equitable.

Key Words: Artificial Intelligence, Reproductive Health, Infertility, ART, IVF.

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Introduction

Infertility is a growing global health problem, with patients often experiencing delays in diagnosis, long waits for evaluation, and widespread dissatisfaction.[1] In recent years, the combination of robotics and artificial intelligence (AI) has played a major role in treating infertility and reducing waiting times.[2]

AI supports data analysis, modeling, and decision-making, helping to improve healthcare planning, increase efficiency, and provide more personalized care for patients undergoing assisted reproductive technology (ART). AI facilitates high output, minimal labor, and efficient operations in procedures such as sperm delivery, embryo processing, and other related processes.[3]

AI and Its Role in Global Fertility Care:

The infertility clinics aim to increase the success rate of in vitro fertilization (IVF) through various modern techniques, including the use of AI. An AI algorithm is used to analyze the embryonic development process through time-lapse images to help doctors select the most suitable embryos for implantation and make the IVF process more efficient. For example, a large IVF clinic in the United States uses an AI-based platform like Vida, which uses deep learning to predict embryo success, thus increasing the chance of pregnancy and reducing the need for multiple IVF cycles.[4] Researchers at the University of Leeds in the UK and The Fertility Partners in North America used AI-based algorithms to assess embryo quality by analyzing real-time images. This reduces the number of embryos transferred, thus increasing overall success and reducing the risk of multiple pregnancies.[5]

One of the countries where AI is advancing in infertility care is India. Platforms that are being driven by AI are aiding in the analysis of ovarian reserve, sperm quality, and embryo selection. In 2020, the IVF clinic NOVA IVF Fertility in India introduced AI in infertility treatment, which led to improved success rates through an automated embryo selection process.[6]

Pakistan's Infertility Landscape:

Infertility is one of the major global health crises, and its prevalence is alarming in developing countries like Pakistan. A recent study in Pakistan showed that around 15-20% of couples suffer from infertility, causing depression and social issues in society.[7] There have been surging requests for additional therapies, which have led to research on technologies such as artificial intelligence (AI) to supplement ART to improve health outcomes in couples.[8]

In Pakistan, fertility care is primarily confined to private health facilities with the provision of IUI (intrauterine insemination), IVF, and ICSI (intracytoplasmic sperm injection), as government healthcare fails to provide sufficient support. This is because of limited resources, inadequate expertise, lack of infrastructure, poor knowledge regarding ART procedures, and a focus on other priority areas like family planning and obstetric care. Although AI has emerged internationally as an essential instrument in healthcare, we have yet to adopt it in our settings. When applied properly, it can offer improved opportunities for diagnosis, patient care, and therapy in settings with limited resources and expertise.[9, 10] The involvement of AI in the hospital environment can provide prospects to bridge these gaps by enhancing daily operations, offering decision support, and facilitating more personalized individual treatment plans.[11]

Machine learning and deep learning are two of the major AI-powered algorithms. If incorporated once in our settings, we can analyze the data accurately and predict the effectiveness of the treatments, helping to select the most viable options.[12] These methods have led to improved evaluation of treatment options for couples and selection of sperm, ensuring successful pregnancy outcomes.[13]

Despite the incorporation of AI in medicine in several Western and neighboring countries, Pakistan hasn't been able to adopt it yet.[14] However, there is at least increasing recognition of AI's potential to improve the accessibility and quality of infertility care in resource-limited settings.[15] Early research indicates that AI-powered diagnostic tools can not only assist in early and effective diagnosis of the reasons for infertility than traditional approaches but also can assist in faster and more successful treatment outcomes.[16] Furthermore, AI-based models are being used to predict patient responses to reproductive therapy, lowering the trial-and-error rate of infertility treatments and optimizing medical resources.[17]

Barriers to Implementation:

Despite the obvious potential for competency in fertility therapy, several challenges remain in Pakistan, including the necessity for good administration, evaluation ethics, and public openness.[18] Cultural and social attitudes towards reproductive assistance impede the implementation of this practice, especially in rural areas where awareness and access to current therapy are limited.[19] Attention should also be paid to one of the major issues of incorporating AI in medicine, specifically in infertility care, which is the ethical issue of privacy and data concerns. This is not just an ethical issue but also a legal issue.[20] The statistics from Pakistan come from various studies and national surveys, which have concluded that infertility rates over the last two decades have been varying between 22%.[21]

In Pakistan, due to a huge disparity between care given by the government and private fertility settings, there is a significant financial burden for individuals from lower socio-economic backgrounds seeking treatment. In addition to the social stigma that already exists, the high expense of infertility treatment makes it less likely for low-income families to seek help. Additionally, it is challenging to give couples timely therapy due to cultural

reluctance and a lack of technology infrastructure. They spend years simply receiving a diagnosis, and by the time they can receive treatment, they are too old for the treatment options.

The effectiveness of AI in determining the causes of infertility may result in more efficient treatment regimens, saving couples money on needless bills. Furthermore, AI can be quite helpful in integrating males into the therapeutic process, which is a cultural problem in Pakistan because social conventions frequently exclude men. AI can assist in balancing the gender dynamics in infertility therapy by providing men with anonymous and less stigmatizing options to participate in their fertility journey. It is crucial to protect privacy and cultural sensitivity. To promote the health and well-being of both partners without going against societal standards, AI systems must be created with cultural norms in mind and encourage male engagement. AI that involves both men and women can lessen the stigma attached to infertility and ease the strain that is frequently put on women. Considering these aspects, AI offers a revolutionary chance to diagnose and treat infertility in Pakistan in a way that is easily accessible, reasonably priced, and culturally aware, easing the financial and psychological strain on families.

AI can display outstanding prospects to transform and uplift infertility care in Pakistan. However, its success will depend on overcoming socio-economic, infrastructural, and cultural barriers, appropriate policies, and stakeholder involvement to ensure equitable access to these advanced technologies.[22] This study aims to highlight the obstacles faced by couples, improve the success rates of incorporating AI in medicine, and look for the development of supportive policies to incorporate AI into fertility medicine in Pakistan.

This review explores the possible application of AI in Pakistan's healthcare system to offer a game-changing chance to close the gaps in the diagnosis and treatment of infertility, especially in government facilities and low-resource settings where such services are absent. People are forced to go for costly private solutions that deplete their life savings because infertility is frequently left untreated in public institutions. By evaluating medical data, finding trends, and producing precise, prompt results, artificial intelligence (AI) can expedite the diagnostic process and save the time and expense involved with conventional techniques. AI-powered systems can also provide private consultations, protecting the privacy and dignity of patients who might be stigmatized in their culture. Infertility services can be morally regulated and standardized by incorporating AI into the healthcare system, guaranteeing fair access for everyone, irrespective of socioeconomic background.

Methodology

We searched for Keywords like ‘AI’s role in Infertility care’, 'IVF’, ‘Infertility’ AND ‘Pakistan’, ‘AI’ AND ‘Infertility’, ‘AI’ AND ‘Infertility’ AND ‘Pakistan’ on Google Scholar, PubMed, The Lancet and Local Sources using BOOLEAN operators such as ‘AND’ and ‘NOT’. Out of the 38 references provided, they were reduced to 10 after checking their eligibility for not having enough information on AI’s role in infertility care, specifically in Pakistan. The remaining 10 were screened for eligibility, and data were compiled from them to construct the tables and the graphs. This evaluation focused on articles regarding AI's role in infertility care in Pakistan over the last decade. The papers were then thoroughly evaluated in light of the study question and aims, excluding those that did not meet the research objectives.

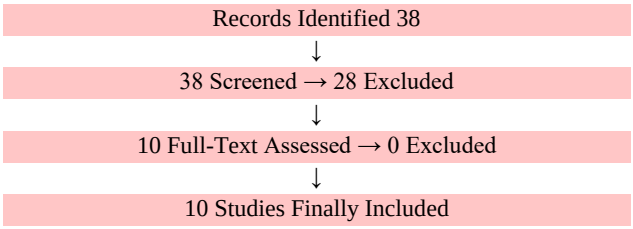

Figure 1. PRISMA Flow Diagram.

Results

Significant gaps and new potential in infertility care within the Pakistani context were found by the narrative review. According to the findings, infertility is very common—estimates range from 21% to 25% and disproportionately affects women because of societal attitudes that place the entire weight of childbirth on them. Despite improvements in reproductive health around the world, Pakistan continues to face obstacles such as restricted access to infertility treatments, poor infrastructure, and social stigmas that prevent candid conversations and prompt interventions. Although still mostly unrealized, artificial intelligence's (AI) potential to close these gaps is encouraging. AI solutions have the potential to completely transform Pakistani healthcare delivery, including individualized treatment regimens, enhanced patient monitoring, and predictive analytics for infertility diagnosis. However, systemic obstacles such as technology constraints, cost, and a shortage of qualified experts with training in AI-driven reproductive health

solutions must be addressed to integrate these technologies. They are provided in the figures and tables below.

Table I compares infertility testing in men and women, showing differences in testing rates, reasons, and cultural factors. Men account for around 20-30% of infertility cases worldwide, while women account for approximately 20-35%; nonetheless, public attention is sometimes disproportionately directed towards women.[23, 24] Women are encouraged to seek testing first due to evident indications such as monthly irregularities, which are cultural stigmas and societal expectations. The graphic also shows that, while women have greater access to clinics, they are typically referred by their partners, reinforcing the gender prejudice that places the infertility burden on women. The findings emphasize the need for AI-powered technologies to close these disparities by standardizing male infertility testing and automating diagnostic processes for both genders.

Table II highlights the key aspects of IVF in Pakistan, where success rates range from 25% to 35%, influenced by factors like age, lifestyle, and clinic quality. Most of the patients are aged between 30–40, though younger women mostly seek treatment. The cost of IVF remains a major barrier, with a single IVF cycle costing PKR 600,000–700,000, which limits accessibility for many below the poverty line. Moreover, IVF treatments are restricted to major cities like Islamabad, Karachi, and Lahore, leaving out rural areas. Cultural stigma and limited awareness further hinder treatment-seeking. Female infertility remains a primary concern, though male infertility cases are rising.

The Figure 2 displays the estimated AI success rates in medicine across four countries: the USA, India, Bangladesh, and Pakistan. The USA leads with a success rate of approximately 85%, reflecting its advanced technological infrastructure, major investments in AI research, and broad adoption of AI in healthcare. India follows with a success rate of 70%, driven by its growing focus on digital health solutions and advancements in AI-driven diagnostics and treatments.

Table I: Comparison of Infertility Testing Between Men and Women.[23, 24]

Factor	Men	Women	Reason for Difference
Percentage Requiring Infertility Testing	20–30% of infertility cases are due to men (ESHRE 2023).	20-35% of infertility cases are due to women (ESHRE 2023).	Cultural stigma and societal expectations often lead to women seeking testing first; also, women have more visible signs (e.g., menstrual irregularities, etc.).
Leading Causes of Infertility	Low sperm count, poor sperm quality and mobility, varicocele, etc.	Ovarian issues, tubal blockages, hormonal imbalances, etc.	Women typically face more visible symptoms (e.g., irregular periods), whereas male infertility can be less noticeable, leading men to seek testing less frequently.
Access to Infertility Clinics	Despite the access, men typically refrain from visiting infertility clinics.	Women have much broader access to infertility clinics and are sent by their husbands.	Clinics tend to focus more on female fertility issues, leading to higher consultation rates for women.
Cultural/Social Barriers	Male infertility is less acknowledged due to societal stigma and cultural barriers.	Women are pushed more to test for infertility, as it is often perceived as their responsibility.	The idea that male infertility is a taboo subject leads to underreporting and fewer visits for male infertility testing. Women are encouraged to test more.

Table II: Key Aspects of IVF Treatment in Pakistan: Success Rates, Costs, and Access.[25]

Aspect	Details
IVF Success Rate	Typically, it is around 25%-35%, but it largely depends on the clinic, locations, and other factors.
Average Age of IVF Patients	Most of the patients are aged between 30-40, but young women are also seeking IVF treatments now.
Cost of IVF Treatment	As of 2023, the average cost of one IVF cycle in Pakistan varies from PKR 830,000 to PKR 970,000, depending on the clinic and type of treatment [25]
Types of IVF Procedures	Normal IVF, Intracytoplasmic Sperm Injection, and egg/sperm donation.
Factors Affecting Success	The main factors are the age of women, lifestyle factors, sperm and egg quality, etc.
Main Causes of Infertility	Usually, it's the female infertility factor, but male infertility is gradually increasing, like low sperm count, poor sperm quality, etc.
Geographical Distribution	IVF treatment is only available in major cities like Islamabad, Karachi, and Lahore. It is not available in rural areas of Pakistan.
Awareness & Education	Despite increasing awareness of IVF treatment, there are still cultural barriers and social stigma that prevent people from seeking IVF treatment.

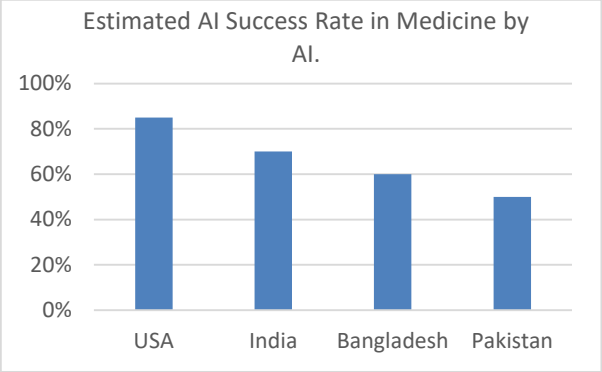

Figure 2. The estimated AI success rate in medicine in different countries as of now, according to AI.

Bangladesh, with an estimated success rate of 60%, demonstrates moderate progress in adopting AI technologies, primarily in urban areas and selected healthcare sectors. Pakistan, however, lags with a success rate of 50%, reflecting the lack of AI not just in medicine but overall. These findings emphasize the urgent need for strategic initiatives to enhance AI adoption in Pakistan, particularly in infertility care.

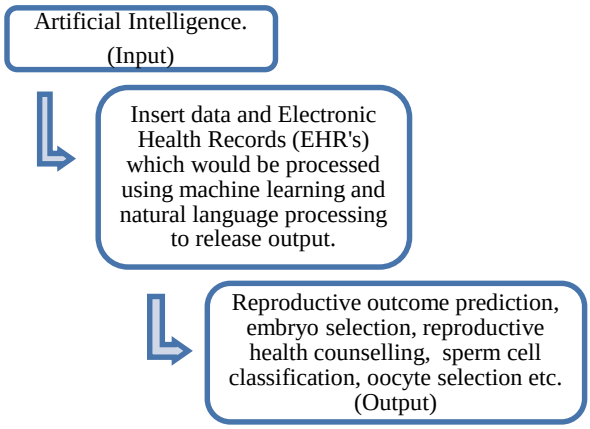

Figure 3. A flowchart diagram representing the summary of AI's use in infertility care.

Figure 3 illustrates the essential role of AI in infertility care by concluding the process from data input to actionable outcomes. It begins with AI systems receiving data, including Electronic Health Records (EHRs), which are then processed using advanced technologies such as machine learning and natural language processing to extract valuable insights in the form of outputs such as reproductive health counseling, embryo selection, oocyte selection, etc.

Discussion

The present study made a comparison between men and women for infertility testing. Infertility is a challenging issue that can deeply affect marital relationships. While both the male and female reproductive systems must work together for successful conception, problems with either partner can result in infertility.[26]

Unfortunately, in many cultures, the focus tends to be on the woman during infertility investigations, leaving her to bear the emotional and social burden, especially in developing countries. Males mostly push women to get tested for infertility without themselves getting checked as well. This often leads to the male factor being overlooked or underdiagnosed.[27]

The World Health Organization (WHO) reports that around 60 to 80 million couples worldwide—about 8-12% of all couples—are affected by infertility.[28] Studies have shown that in approximately 40% of these cases, male factors contribute to infertility, while 30% are due to female factors. The remaining 20% involves issues in both partners, and in about 10% of cases, the cause remains unexplained. This portrays that the male factor is more contributing to infertility.[29]

According to estimates by the World Health Organization (WHO), male factors contribute to approximately 50% of infertility cases among couples. Male infertility can result from various medical conditions, including comorbidities like liver failure, kidney disease, chronic obstructive pulmonary disease, and multiple sclerosis. Lifestyle factors, certain cancers, medications, hormonal imbalances, varicoceles, and, more recently, sperm DNA fragmentation, can also play a role in male infertility. Essentially, any medical condition that disrupts hormonal balance, sexual function, or sperm production could potentially contribute to infertility in men. Despite this, around 30% of male infertility cases remain unexplained.[30]

The initial evaluation of male infertility typically involves gathering a detailed reproductive history and analysing one or two semen samples. Key characteristics assessed include sperm concentration, total sperm count, motility, vitality, and morphology. Additional diagnostic steps may include hormonal testing, genetic testing, and diagnostic procedures to better understand the problem.[31]

AI has become increasingly important in analysing medical images and learning to recognize patterns, making it particularly valuable in specialties like radiology, pathology, ophthalmology, and dermatology—fields that heavily rely on visual data. The ability of AI to minimize common errors in daily clinical practice and make real-time predictions holds great promise for improving healthcare outcomes. [32, 33]

As illustrated in Figure 2, AI would be the input and would be provided with the data and Electronic Health Records (EHRs). This would lead to the processing of the data and health records. In conclusion, it would provide Infertility treatment counseling, help in sperm and oocyte selection, reproductive outcome prediction, etc.

Not enough data was available on the percentage success of AI in medicine because it hasn't yet been incorporated fully into medicine. However, estimates from AI studies display that Pakistan would have a ½ success of AI in medicine, while the USA, India, and even Bangladesh is higher than Pakistan. This shows the lack of technology available in the medical field in Pakistan. AI could be incorporated into medicine in some major hospitals in Pakistan, but to completely engulf it would take some time.

The United States has led the way in adopting Artificial Intelligence/Machine Learning (AI/ML) equipment in medicine. Between 2015 and 2020, the FDA approved 222 AI/ML-based medical devices, which has led to significant growth of AI in the field of medicine. To aid and review the development of these AI/ML devices, the agency has issued guidance and established a software precertification program. Many gadgets are being developed that employ artificial intelligence algorithms to improve picture analysis, identification, and diagnosis. Furthermore, approval is growing for AI-powered clinical decision-making procedures that aim to advise clinicians and enhance patient outcomes. Efforts to give clear rules and encourage innovation can help the United States become a centre for the development of AI/ML-powered medical devices. If work continues at this pace, the United States will likely be the front runners for the availability of promising AI/ML-based medical tools.[34,35]

One of the countries where AI is advancing in infertility care is India. Platforms that are being driven by AI are aiding in the analysis of ovarian reserve, sperm quality, and embryo selection. One of the IVF clinics in India, NOVA IVF Fertility in India in 2020, introduced AI into infertility treatment, which led to improved success rates and an automated embryo selection process. Moreover, AI is being involved in creating personalized treatment protocols, which are reducing the need for repeated cycles and unnecessary interventions. This aids in managing the financial and emotional burden on the patients.[6] India's predicted success rate of using AI in medicine is around 70%. This is 20% higher than Pakistan's. Despite not many cultural differences, Indians have much more success in the information technology industry due to much more exposure to education in the local population.

Bangladesh, a densely populated country, has also made some progress towards the use of technology in medicine. To counter the multiple challenges comprehensively, the Government of Bangladesh (GoB) has actively adopted advanced technologies to elevate the quality of health care services. Initiatives such as District Health Information System 2, the open medical record system, and the open-source smart register platform have revolutionized health data collection and service delivery.[36] However, AI tools need to be used ethically and effectively.[37]

The development of in vitro fertilization (IVF) has revolutionized assisted reproductive medicine, offering new possibilities for individuals dealing with infertility globally. In Pakistan, where the infertility rate is 21% in a population of around 250 million, access to IVF remains restricted. Infertility is frequently accompanied by strong social stigma, especially for women, and when coupled with widespread poverty, approximately 40% of the population lives below the poverty line—many couples are deterred from seeking IVF treatment [[38]. In 2023, it was reported that the average cost of one IVF cycle in Pakistan is around 600,000-700,000. In a developing country like Pakistan, even infertile males and females would hesitate to go for IVF at this cost. Plus, since it is only available in major cities, thus, people would need to take time out of their schedules, which they may be unwilling to do.

Furthermore, public awareness of IVF is low, with 78% of the population unaware of its existence. Misconceptions about IVF, such as concerns over multiple births, caesarean sections, and birth defects (with a minimal increase of around 1%), contribute to further reluctance in seeking treatment. Additionally, the limited availability of IVF facilities and trained professionals in the country creates a geographical barrier, particularly in rural areas.[38]

Although there is a disconnect between traditional practices and modern medicine, religious beliefs and cultural customs continue to significantly influence attitudes toward infertility treatments. As a result, awareness of advanced treatments like IVF remains very limited in Pakistan, partly due to its restricted availability. In a study, among those who are familiar with IVF, 55% viewed it as unacceptable, citing concerns that it may be prohibited in Islam or that it involves the use of foreign sperm or eggs. This suggests that even among the small number of people who are aware of IVF, there is significant misinformation. Concepts of self-care and

puberty changes should be taken into account while developing interventions.[39] An improvement in the MCH indicates a nation's overall socioeconomic progress.[40] Many individuals may not realize that IVF and similar reproductive technologies are permitted in Islam, provided that they do not involve third-party donations.[41, 42] While IVF has been more widely discussed and implemented in other Islamic countries, such as Iran, this issue warrants further exploration and open dialogue in Pakistan.[43] Pakistan has lagged, but it still has time to match international standards if Pakistan catches up with them quickly.

Limitations: The biggest limitation in assessing the role of AI in infertility treatment is the limited data. Much of the research in this area is still in its infancy due to small studies and a lack of large, comprehensive data. This makes it difficult to draw general conclusions about the effectiveness of AI across cultures and clinical settings. Additionally, data privacy concerns play a significant role in limiting access to detailed medical records. Since infertility treatments involve patient data, ethical and legal issues make it difficult to collect the large amounts of data needed to train AI models. The scarcity of data in Pakistan is a study constraint.

Conclusion

The expected benefits of incorporating AI into infertility care include increasing the accuracy of early diagnosis, thereby reducing the time to discover the cause of infertility. Personal communication using AI will increase patient satisfaction. Simple, clinically-based monitoring can improve treatment adherence and outcomes. To use the full resources of AI in infertility care, it is necessary to invest in different data, different data representing different cultures. In addition, increased knowledge and education of doctors and patients will increase trust in AI technology. It is important to create policies that will ensure the equitable use of AI in antibiotics. Collaboration between AI developers, practitioners, and policymakers is needed to integrate AI solutions into healthcare and ensure that these solutions are accessible, safe, and applicable to all patients. By integrating these AI technologies into infertility care, patients and doctors can experience more personalized, efficient, and successful treatments, ultimately improving fertility and health outcomes in Pakistan and beyond.

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