Artificial Intelligence in Assisted Reproductive Technology

INTRODUCTION

The intersection of mythology, the Middle Ages and the modern world provides a fascinating backdrop for examining the evolution of assisted reproductive technology (ART) and the integration of artificial intelligence (AI). From the ancient Indian epics of Mahabharata and Ramayana to the Middle Ages, where scientific understanding was limited, and finally, to the modern era marked by AI-powered innovations, the quest for overcoming infertility has been a constant.[1] This commentary delves into this journey through time, exploring the role of AI in ART, ethical considerations, and the profound implications for individuals and society.

MYTHOLOGICAL ORIGINS: DESIRE FOR OFFSPRING

The Mahabharata and Ramayana, ancient Indian epics, are steeped in mythological tales that echo the timeless human desire for offspring. These stories vividly depict characters grappling with infertility, embodying the profound longing for children.

In the Ramayana, King Dasharatha and Queen Kausalya's yearning for an heir leads to a divine intervention through a ritual, resulting in the birth of Lord Rama. Similarly, the Mahabharata features Queen Kunti's invocation of deities to fulfil her desire for children, leading to the birth of the Pandavas. The technique that was used to fulfil their desire to become parents seemed very similar to the assisted reproductive technique we use nowadays. It might be true that our ancestors had reached this far to use the ART technique to treat infertility, but this advancement vanished over centuries, and the same cycle has started again, from the basic treatment of infertility to ART, and now AI in ART.

These mythological narratives underscore the enduring human desire for progeny and the extraordinary lengths to which individuals have historically gone to realize this aspiration. In the context of AI in the ART, the journey from these ancient narratives to the Middle Ages reveals a gradual shift towards more scientific approaches.

THE MIDDLE AGES: LIMITED UNDERSTANDING AND SPIRITUAL BELIEFS

During the Middle Ages, scientific understanding of human reproduction was rudimentary. Medical knowledge was often intertwined with spiritual beliefs, and infertility was frequently attributed to divine will or moral failings.

Infertility treatments in this era were often rooted in superstition and religion, with various rituals and prayers being performed to seek divine intervention. These practices would offer solace, emotional support, and strength to those facing the issue of infertility; however, they lacked the scientific basis and effectiveness that modern ART and evidence-based medicine provide.

THE MODERN WORLD: AI-POWERED ADVANCES IN ART

AI is one of the most promising areas of research in computer science. With its rapid technological advancement, upgradation, and vast numbers of applications, AI is rapidly becoming pervasive. This increasing use is due mostly to its robust applicability to problems that are too complicated to be solved by humans or traditional computing structures.[1-4] AI tools can process, scrutinize, and analyze a great amount of data in a short time.

The transition from the Middle Ages to the modern world brought about significant advancements in medical science and technology. ART emerged as a viable solution for infertility, offering hope to countless individuals and couples, and the combination of ART and AI might give promising results to the commissioning couples.

Can AI replace God?

AI and God differ in their existence, origins, consciousness, and abilities. AI is a technological creation developed by humans through programming and algorithms, and lacking self-awareness and

consciousness. In contrast, God is often seen as a supreme being originating from religious beliefs, possessing a transcendent consciousness and intelligence beyond human comprehension. While AI excels in specific tasks based on data and algorithms, God's abilities extend to limitless powers like creating the universe and controlling natural phenomena. AI is accepted through empirical evidence, while belief in God is often a matter of faith and personal perspectives.

Though I donot have personal opinions or beliefs, but sometimes I start comparing God with AI.

The concept of a deity, such as God, is deeply rooted in religious and philosophical contexts. While AI is advancing rapidly, it is highly unlikely for AI to replace God, as God is often considered a spiritual and metaphysical concept that transcends the capabilities of technology. Additionally, belief in God encompasses various cultural, personal, and religious aspects that are unlikely to be replicated by AI alone.

Can AI create perfect designer babies?

The creation of ″designer babies″ typically refers to the process of selecting or modifying specific genetic traits in embryos, resulting in desired characteristics in a future individual. AI can play a role in assisting with the analysis of genetic data, the identification of potential gene combinations, or the prediction of certain traits or outcomes based on genetic information. However, it is important to note that the actual creation and modification of embryos involve complex scientific and ethical considerations beyond the capabilities of AI alone. The process of creating designer babies raises profound ethical questions and is subject to legal and regulatory restrictions in many countries. Thus, while AI can contribute to the genetic analysis aspect, the creation of designer babies involves broader discussions and decision-making involving scientists, medical professionals, ethicists, policymakers, and society as a whole.

Can AI replace modern day IVF laboratories?

AI has the potential to enhance and improve various aspects of modern IVF laboratories, but it is unlikely to completely replace them. AI can aid in the analysis of large volumes of data, optimize processes, and provide decision support to embryologists and clinicians. It can help in selecting the best embryos for implantation based on various factors such as morphology, genetic information, and time-lapse imaging.

Additionally, AI can improve the efficiency and accuracy of sperm and egg selection, embryonic development monitoring, and cryopreservation techniques. It can also assist in predicting the likelihood of successful outcomes and optimizing treatment protocols based on individual patient characteristics.

However, IVF laboratories require highly skilled embryologists, scientists, and clinicians who can handle complex procedures, perform delicate manipulations, and make critical decisions based on clinical judgment. The expertise and human touch are still essential in many aspects of IVF treatments, such as performing delicate procedures, providing emotional support to patients, and adapting to individual patient needs.

Therefore, while AI can certainly enhance and revolutionize IVF laboratories, it is unlikely to completely replace the need for human expertise and involvement in the near future. The integration of AI technologies into IVF labs is more likely to result in a partnership between human professionals and AI systems, working together to improve outcomes and provide better patient care.

The role of AI in assisted reproductive technology in the modern world

Some important which can be played by AI in the field of reproductive medicine.

(1) **Personalized treatment plans** − AI algorithms analyze vast datasets, including genetic information and medical histories, to tailor fertility treatment plans for individual patients. This personalization increases the chances of successful conception while minimizing risks. By helping with this, it can reduce face-to-face medical contact and thus increase the medical and user productivity.

(2) **Predictive analytics** − AI can predict the success rates of specific ART procedures, enabling couples to make informed decisions about their treatment options.[5] This reduces the emotional and financial burdens associated with unsuccessful attempts.

(3) **Quality control in embryo and gametes selection** − AI-powered image analysis tools assist embryologists in selecting the healthiest embryos for implantation during in vitro fertilization (IVF). It may also assist with selecting the best male and female gametes. The quality of oocytes is associated with follicle size, morphology, and their cytoplasmic characteristics. In terms of male gametes, morphology, concentration, and motility are some known parameters that are directly correlated with

IVF success.[6,7] However, the selection of gametes is prone to a high degree of variation between operators. AI can be transformative in this aspect. This technology can enhance success rates of ART and minimizes the risk of multiple pregnancies and inter-observer variability.

The benefit of AI might be of great importance if it helps with the selection of the best sperm for intracytoplasmic sperm injection (ICSI), a process currently performed by the embryologist. The need for the development of new assessment criteria for sperm selection might arise once we start using unsupervised AI for this function.

AUTOMATIC MEASUREMENTS OF FOLLICULAR DIAMETER WITH 3D ULTRASOUND

Ultrasound follicular count (antral follicle count, AFC) is an impeccable tool for measuring ovarian reserve, whereby the number of oocytes retrieved in IVF cycles is predicted by the estimated number of follicles responsive to FSH and may be the basis for individualized ovarian stimulation therapy. Advances in the ultrasound technology have recently led to the improvement in resolution and quality of the image.[7,8] The automatic measurements of follicular diameter by using some specific 3D software are connected to several advantages:

(1) Examination time is can be saved as the ultrasound scan data are stored,
(2) This technique reduces the operator's influence on scan interpretation and objectivity; therefore, interobserver variability will be reduced.
(3) Using AI analyzed follicular volume obtained with automated measurements of follicular as the measure of follicular growth combined with volume-based criteria for the hCG triggering, improve the treatment outcome compared to that achieved with conventional monitoring with follicular diameter.

The AI ART software can analyze in detail all informations by automatic measurements of follicular diameter with 3D ultrasound to monitoring the cycle and hCG triggering.

OPTIMIZING MEDICATION PROTOCOLS

AI algorithms optimize medication dosages and timing, reducing side effects and improving treatment outcomes. This precision minimizes the physical and emotional toll on patients.

PREIMPLANTATION GENETIC TESTING (PGT)

PGT is becoming pervasive now in genetic practices and ART, with more than one-third of ART Centers in the USA already utilizing PGT technology. The current selection process of embryos has an extremely high developmental potential and requires further improvement in this field, as well as substantial proportion of transferred euploid embryos still fail to get an ongoing clinical pregnancy.

In order to avoid the potential damage of embryo biopsy procedures, one of the greatest challenges will be the development of non-invasive approaches to PGT, optimization, and automatization in AI ART software. If we got success in developing such software, then it would be a big breakthrough in genetic science and would exponentially increase the success rate of IVF cycles because of decreasing transplantation failure, at least due to genetic causes.

Ethical considerations in the age of AI

The integration of AI into ART raises critical ethical considerations:
(1) **Data privacy** − The collection and analysis of sensitive patient data must adhere to strict privacy regulations to protect patient information.[9,10]
(2) **Transparency** − Ensuring transparency in AI systems used for fertility treatment is essential to build and maintain patient trust.
(3) **Equity** − Access to AI-enhanced ART should be accessible to individuals across all socioeconomic groups, addressing disparities in fertility care.
(4) **Autonomy** − AI recommendations should support, rather than replace, the informed choices of patients and healthcare providers, ensuring that patients have the final say in their treatment plans.

Implications for individuals and society

(1) **Increased success rates** − AI-driven personalization and predictive analytics significantly increase the likelihood of successful ART outcomes, reducing the emotional strain of repeated treatments.[11]
(2) **Reduced costs** − AI optimization of treatment plans can help lower the financial burden associated with fertility treatments, making ART more accessible.
(3) **Improved patient experience** − AI streamlines processes, reduces wait times, and enhances communication between patients and healthcare providers, ultimately leading to a more positive patient experience.

Table 1: Hurdles and requirements in infertility clinics

Hurdles:
- Most clinics are too small in isolation to have sufficient data for AI.
- Limited computing power and data storage.
- Discrepancy in recorded and reported patient characteristics and reproductive outcomes between clinics.
- Variation between studies in the input parameters used for AI to predict reproductive outcomes

Requirements to develop AI in the infertility service
- Consortia to develop standardized and detailed recording and reporting of patient data.
- Multi-clinic sharing of anonymized patient data.
- Increased computing power and data storage.
- Consensus on input parameters used in AI for predicting reproductive outcomes.
- Rigorous, high quality, multi-Center, peer-reviewed validation studies for AI algorithms.

Hurdles in the way of AI as a trustworthy tool in ART

As per Chow et al.[14] study, some very crucial steps towards adoption of AI in the IVF clinic. The box given below comprises potential hurdles which most of the IVF clinic will face while introducing AI in their set-up [Table 1]. It might appear a daunting task, however, good outcomes can be achievable with use of AI by making some changes in their setting and adopt a holistic approach for it.[12-14] [Figure 1]

CONCLUSION

The journey through time, from the ancient Indian epics of the Mahabharata and Ramayana, where divine interventions were sought to fulfill the desire for offspring, through the Middle Ages with limited scientific understanding and spiritual beliefs, to the modern world marked by AI-powered innovations, reflects humanity's unyielding quest to overcome infertility.

In the past, there existed a spiritual intelligence capable of artificially regulating reproductive technologies.

In the present day, humans' technical intelligence is artificially connecting the mind and computer-generated laboratories in the cloud, instantly interpreting outcomes in reproductive medicine.

There may come a time in the future when humans can create flawless beings similar to the gods of ancient times. Let us observe what AI will accomplish, is capable of, and may reverse in the future.

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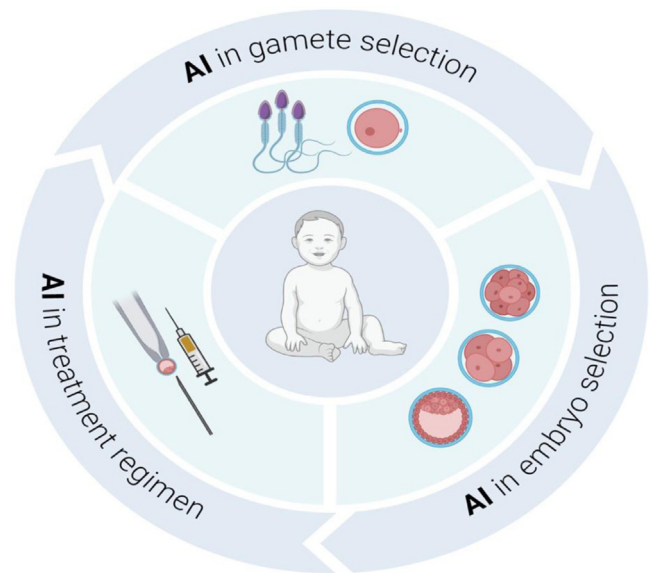

Figure 1: Emerging role of artificial intelligence (AI) in the in vitro fertilization (IVF) clinic. AI represents an opportunity for technological advancement to improve IVF success. It is multifaceted in its capability. For example, AI may aid in selecting the best oocyte and sperm combination as well as predicting embryo quality. Furthermore, AI may assist the clinician in developing an optimal patient-specific treatment regimen to improve IVF success.

supreme being originating from religious beliefs, possessing a transcendent consciousness and intelligence beyond human comprehension. While AI excels in specific tasks based on data and algorithms, God's abilities extend to limitless powers like creating the universe, and controlling natural phenomena. AI is accepted through empirical evidence, while belief in God is often a matter of faith and personal perspectives.

Despite many obstacles on the way, it is undeniable that AI has a future role in the IVF field. However, AI must overcome hurdles prior to its utilization. AI requires not only extensive simulation studies, research and publications in peer-reviewed journals but also rigorous validation in numerous clinics and in different patient populations.

AI may emerge as a powerful ally in assisted reproductive technology, offering personalized treatment plans, predictive analytics, quality control in embryo selection, and medication protocol optimization. However, ethical considerations such as data privacy, transparency, equity, and patient autonomy must guide its integration.

As AI continues to evolve, its role in ART promises to bring new hope to individuals and couples seeking to build their families, echoing the age-old desires portrayed in mythology while harnessing the advancements of the modern age.

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Conflicts of interest
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