



## Perspective

## Impact of industrial revolution 4.0 on reproductive health and infertility management

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Fourth Industrial Revolution also known as the Industrial Revolution 4.0 (IR 4.0), has brought significant changes and advancements in various industries, including healthcare.<sup>1</sup> The integration of advanced technologies such as artificial intelligence (AI), the Internet of Things (IoT), and big data analytics has transformed the way healthcare is delivered and has led to significant benefits for human health.<sup>1</sup>

Some of the key impacts of IR 4.0 on human health are: (a) *Improved diagnosis and treatment*: with the use of AI and machine learning, healthcare providers can access vast amounts of patient data and use it to make more accurate diagnoses and develop personalized treatment plans<sup>2</sup>; (b) *Telemedicine*: The widespread use of connected devices and the internet has made it possible for patients to access medical advice and treatment from the comfort of their homes. This has been especially beneficial for people living in remote or underserved areas; (c) *Electronic health records (EHRs)*: The use of electronic health records has improved the accuracy, efficiency, and accessibility of medical information. This has helped to reduce medical errors and improve patient outcomes; (d) *Predictive analytics*: The use of big data analytics in healthcare has allowed healthcare providers to analyze vast amounts of patient data to identify patterns and make predictions about future health outcomes. This has helped to improve population health and prevent disease; (e) *Wearable technology*: Wearable devices such as smartwatches and fitness trackers have become increasingly popular and are providing valuable health data to users and healthcare providers. This data can be used to track and monitor health trends, identify potential health problems, and support disease management.<sup>2</sup>

Infertility is a complex issue that can have many underlying causes,

such as hormonal imbalances, structural problems with the reproductive system, and lifestyle factors.<sup>2</sup> The Fourth Industrial Revolution may play a role in the development and improvement of assisted reproductive technologies.<sup>3</sup> Advances in AI and robotics could lead to the development of more precise and effective techniques for monitoring and manipulating the growth and development of embryos *in vitro*.<sup>3</sup> Additionally, the use of big data and analytics could help doctors and researchers better understand the underlying causes of infertility and develop more effective treatments.<sup>2</sup> With the increasing availability of powerful computing tools, AI can analyze vast amounts of patient data and identify patterns that are not immediately apparent to human clinicians. AI can help doctors identify the underlying causes of infertility by analyzing patient medical histories, laboratory results, and imaging studies. For instance, machine learning algorithms can analyze sperm and egg characteristics and provide insights into possible infertility causes. AI can also help doctors monitor the progress of treatment and adjust the treatment plan as needed. AI can play a role in the automatic diagnosis of infertility-related imaging examinations. For example, AI can analyze ultrasound images and identify abnormalities that may contribute to infertility. This can help doctors make more accurate diagnoses and provide more targeted treatments. The use of AI in infertility diagnosis and treatment has several advantages, including increased accuracy, reduced diagnostic errors, and improved treatment outcomes. Additionally, AI can help doctors identify patients who are at risk for infertility and provide preventive interventions.

While the IR 4.0 has the potential to bring about many positive changes in many areas, it is not completely explored how it could

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specifically solve infertility problems in couples. The significance of this revolution in reproductive health lies in the potential for technology to greatly improve access to information, resources, and services related to reproductive health. For example, telemedicine and other forms of remote healthcare delivery can make it easier for people, especially those in rural or remote areas, to access information about reproductive health and connect with healthcare providers for consultation and treatment. Mobile health applications can provide individuals with easy access to information about contraceptive options, sexual health, and prenatal care, as well as tools for tracking menstrual cycles and managing reproductive health.<sup>4</sup>

Additionally, technological advancements in medical devices and procedures can improve the quality and accuracy of diagnostic tests and treatments related to reproductive health.<sup>5</sup> For example, there are now non-invasive prenatal tests that can be used to test for genetic abnormalities in a fetus, and minimally invasive surgical procedures that can be used to treat conditions like fibroids or endometriosis.<sup>5</sup>

Male infertility is a major global concern as almost half of the infertility cases bear a male contributing factor. Male infertility is determined by evaluating sperm concentration, motility, and morphology. Clinical diagnostic laboratories typically use a combination of manual and automated methods, such as computer-assisted sperm analyzers to analyze semen.<sup>6</sup> However, manual semen analysis is time-consuming, requires skilled technicians, and can result in subjective and inaccurate results. Automated analysis is more accurate, but requires expensive equipment, which limits its accessibility. Additionally, the process of obtaining a semen sample can be uncomfortable for men, making it difficult to diagnose infertility. To address these challenges, home-based sperm testing has become available, offering a convenient and private alternative for men. Several home-based male fertility tests, such as SpermCheck and Trak Male Fertility Testing System, have been approved by the FDA.<sup>7</sup> However, these tests only measure sperm concentration, not motility or shape, which are also important indicators of sperm quality. While there are many mobile health applications (MHAs) that have been created to assist men with infertility issues, the quality and adherence to standards remain questionable. According to one study, the current MHAs available are not always a reliable source of information on male infertility. The ideal MHA should be based on scientific evidence, be easy to use, respect privacy and security laws, and empower patients by giving them the confidence and ability to make changes to their behavior or attitudes.

Mobile applications have also become popular for women's reproductive health and infertility management. Many apps can help women track their menstrual cycle and ovulation, making it easier for them to predict when they are most fertile. Some apps allow women to log information about their menstrual cycle, basal body temperature, and other fertility indicators, giving them a better understanding of their reproductive health.<sup>8</sup> Apps can provide women with information and support during pregnancy, including daily tips and reminders, fetal development updates, and appointment tracking. Some apps offer support and resources for women facing infertility, including information about treatments, support groups, and mental health resources. Women can track their menstrual cycles, including symptoms, moods, and pain levels, to better understand their bodies and manage their overall health.<sup>8</sup> Mental health is also a crucial aspect of reproductive health, and many apps offer resources and support for managing stress, anxiety, and depression related to fertility and infertility. Overall, mobile apps can be a valuable resource for women to manage their reproductive health and infertility, offering access to information and support, and helping to promote overall well-being. Infertility and its treatment often cause significant emotional stress for women, men, and couples, with more female partners reporting this stress.<sup>9</sup> There is an increasing amount of research into the efficacy of self-administered mental health interventions delivered through online and smartphone technology. Mindfulness-based

interventions, such as Mindfulness-Based Stress Reduction (MBSR), be effective in reducing psychological symptoms and improving overall well-being for people in clinical and non-clinical settings. The key advantage of these tools is their ability to make low-intensity psychological support available to a large audience at a low cost. Given the emotional stress of infertility and its treatment, as well as the time commitment involved, people undergoing fertility treatments would benefit from easily accessible, low-intensity strategies to improve their mental health.

A recent investigation carried out on reproductive endocrinology and infertility (REI) mobile applications (apps) available on Apple iTunes and Google Play stores aimed at REI providers, has ranked and identified the most useful apps.<sup>10</sup> According to the study, out of 2179 apps evaluated, only 0.32%, were deemed useful for REI providers.<sup>10</sup> This suggests that there is room for improvement and development in the area of REI mobile resources, considering the limited number of useful apps and their varying degrees of quality and comprehensiveness.

The IR 4.0, characterized by the convergence of digital, biological, and physical technologies, has led to unprecedented advancements in artificial intelligence (AI) tools such as Chat-GPT. It is a promising asset in the field of reproductive health and infertility management. By leveraging natural language processing, machine learning, and big data analysis capabilities, these AI tools have the potential to significantly impact patient care, clinical decision-making, and research in reproductive medicine.<sup>11</sup>

Overall, IR 4.0 has the potential to greatly enhance access to information, resources, and services related to reproductive health, ultimately leading to improved health outcomes for individuals and communities. At present, while the Fourth Industrial Revolution may not directly solve infertility problems in couples, it may play a role in the development of new and improved management for infertility, making it easier for couples to avail treatments. However, it is important to note that the implementation of these technologies must be done with caution and consideration for privacy and ethical concerns. The vision of the future in AI-mediated reproductive healthcare is to use AI algorithms to analyze large datasets, including medical history, genetic information, lifestyle factors, and environmental exposures, to provide accurate predictions and diagnoses for reproductive health issues. This can help to optimize fertility treatments, improve pregnancy outcomes, and prevent reproductive disorders. One potential research direction in AI-mediated reproductive healthcare is the development of predictive models for fertility outcomes. AI algorithms can analyze complex data sets to identify factors that affect fertility, such as age, genetics, lifestyle, and medical history. This information can be used to develop personalized treatment plans that can improve the chances of a successful pregnancy. Moreover, AI can be precisely used to improve pregnancy outcomes. AI algorithms can analyze data from prenatal monitoring, including fetal monitoring, maternal health, and environmental exposures, to identify potential risks and develop proactive interventions. AI can also be used to monitor the health of the fetus and mother during pregnancy and identify potential complications in real time. Additionally, AI can be used to prevent reproductive disorders by identifying individuals who are at high risk of developing certain conditions. For example, AI algorithms can analyze genetic data to identify individuals who are at risk of developing hereditary reproductive disorders such as polycystic ovary syndrome (PCOS) and endometriosis. This information can be used to develop targeted prevention strategies. Additionally, in the era of IR 4.0, genetic technologies have greatly advanced and transformed the field of reproductive medicine. These technologies enable precise identification of genetic abnormalities, helping to diagnose and prevent genetic disorders before or during pregnancy. *In-vitro* fertilization (IVF) has also benefited from genetic technologies such as preimplantation genetic testing (PGT), which allows for the selection of embryos with a lower risk of genetic disorders. Additionally, gene editing tools like CRISPR-Cas9 offer the

potential for the correction of genetic defects and the creation of genetically modified embryos, although ethical and safety concerns remain. On the whole, the vision of the future in AI-mediated reproductive healthcare is to improve the efficiency and effectiveness of reproductive healthcare by providing personalized solutions to individuals and healthcare professionals. Potential research directions include predictive models for fertility outcomes, improving pregnancy outcomes, and preventing reproductive disorders.

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