Let's Talk Fertility, Recent Technological Advances in Fertility Care: A Narrative Review

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Abstract

Infertility affects approximately one in six couples in Ireland and continues to be a growing clinical and social challenge. Assisted reproductive technologies (ART), namely in-vitro fertilization (IVF) and intracytoplasmic sperm injection (ICSI), have facilitated tremendous advances in fertility care, but success rates remain low, and patients continue to face challenges including cost and access to services. Emerging technological advancements in artificial intelligence (AI), preimplantation genetic testing (PGT), and telemedicine are transforming fertility care with the potential to overcome many of these barriers. AI integrates individualization with technology to personalize strategies for fertilization and clinical decision making to improve safety and success in each IVF cycle. Advances in PGT, including next generation sequencing (NGS) and non-invasive pregenetic testing (niPGT) show promise in screening and detection of genetic abnormalities which contribute to optimizing reproductive outcomes. Telemedicine allows for expansion of access to fertility care beyond traditional settings, helping to overcome barriers including geographical distance and increasing access to fertility health services. Collectively, these advances are shifting fertility care towards individualized, precise, and accessible care, with the potential for global impacts on reproductive outcomes.

Introduction

Infertility represents a significant and growing global health challenge, with approximately 1 in 6 couples of reproductive age experiencing infertility during their lifetime.1 Infertility is defined as the inability to successfully conceive after 12 or more months of consistent unprotected sexual intercourse. In Ireland, the Health Service Executive (HSE) estimates a similar prevalence, with approximately 1 in 6 heterosexual couples affected, consistent with global figures.2

/In response to this challenge, the integration of assisted reproductive technologies (ART) into fertility care has tremendously improved reproductive outcomes. In particular, in-vitro fertilization (IVF), and intracytoplasmic sperm injection (ICSI), have been instrumental in enabling many individuals and couples to achieve pregnancy.3 Since its first introduction in 1978, ART use has increased dramatically from 140,000 cycles in 1991 to 3.2 million in 2018, making it one of the most impactful therapies in fertility care to date.4

Similar growth is reflected in Ireland, with IVF cycles rising considerably in recent years, especially following introduction of publicly funded fertility treatment in 2023 which allowed for greater and more affordable access.2

Despite these advances, ART is burdened by high financial costs and suboptimal success rates, with only 40% of cycles resulting in pregnancy and even fewer leading to live births.5 Consequently, there is a continuing need for new and improving techniques in fertility care. This review aims to examine the emerging roles of artificial intelligence (AI), preimplantation genetic testing (PGT), and telemedicine in enhancing the efficiency and accessibility of fertility services.

Artificial Intelligence for Personalized Fertility Care

The use of AI in reproductive medicine has expanded rapidly, promoting personalized care through precise embryo selection, analysis of patient specific data to optimize IVF protocols, and prediction of outcomes.5 A major advancement in this field has been AI-assisted embryo imaging, which enables precise evaluation of embryo morphology, viability, quality, and implantation potential.6,7 In parallel, AI has been applied to sperm selection through advanced sperm analysis and AI-assisted microfluidic sorting to improve the selection of highly motile and genetically stable sperm.8,9

Beyond embryo selection, AI also facilitates personalized fertility care by using individual level data to inform and guide IVF management. AI models can be used to personalize ovarian stimulation protocols, optimizing the dose and timing of stimulation to improve oocyte retrieval outcomes.10,11 Furthermore, this approach may also help reduce complications such as ovarian hyperstimulation syndrome (OHSS) or multiple pregnancies.3 Given that the success of IVF largely depends on having a sufficient number and quality of oocytes, AI-guided personalization of strategies for identification and retrieval of such oocytes impacts clinical decision making and is a clinically meaningful application of personalized medicine.

While these advances show tremendous promise, patient privacy, ethical concerns surrounding autonomy and dehumanization remain barriers to its widespread implementation into clinical practice.12

Advances in Preconception Genetic Testing

Genetic testing has become an integral part of ART by providing a framework for more informed embryo selection. PGT allows for the detection of chromosomal or inherited genetic abnormalities in embryos developed through IVF prior to implantation.13 Various types of preimplantation genetic testing (PGT) can screen embryos for aneuploidy, defined as an abnormal number of chromosomes, monogenic disorders caused by mutations in a single gene, and structural chromosomal rearrangements, including translocations, which involve alterations in chromosome structure. Therefore, PGT is commonly indicated in cases of known genetic disorders, advanced maternal age, recurrent pregnancy loss, or repeated implantation failure.14

In recent years, PGT has advanced with the development of next-generation sequencing (NGS) and non-invasive DNA sampling methods. NGS offers a low-cost, highly sensitive and specific alternative to earlier methods by enabling parallel sequencing of millions of DNA fragments and assembling them using bioinformatics.15 It can detect microdeletions, which are small missing segments of a chromosome, microduplications involving extra copies of small chromosomal segments, and mosaicism, defined as the presence of two or more genetically distinct cell lines within an embryo, and has been associated with improved implantation and live birth rates.16–18 However, despite these advantages, conventional NGS-based PGT approaches remain less effective at detecting chromosomal rearrangements, which may be missed due to absence of overall chromosomal number changes.19 Beyond sequencing advances, genetic sampling techniques have also evolved giving rise to non-invasive PGT (niPGT).Unlike traditional PGT which relies on day-5 trophectoderm biopsy, niPGT analyzes cell-free DNA in culture media.

This reduces embryo manipulation, procedural complexity, and cost, while avoiding a technically challenging procedure with potential health implications.20 It is clear that niPGT has safety and technical benefits, however, it lacks robust evidence supporting its efficacy,21 highlighting the need for further optimization and validation to improve DNA quality and yield.

Telemedicine: Expanding Access and Efficiency in Fertility Care

The introduction of telemedicine, using information and communication technologies to deliver fertility healthcare services, has led to major advancements in the accessibility and efficiency of fertility care.22 Telemedicine in reproductive care has enhanced the patient experience while maintaining pregnancy outcomes and complication rates comparable to traditional in-person care. 23,24 Notable advantages include reduced wait times for specialists and earlier initiation of fertility treatment, with some studies reporting wait time reductions by up to 120 days.25 Furthermore, telemedicine diminishes several well-recognized barriers to fertility care, including geographic distance and socioeconomic disparities such as low income and lack of insurance.23,26,27 By expanding the geographic reach of fertility services, telemedicine allows clinics to treat patients in remote or underserved areas without compromising pregnancy outcomes or patient satisfaction.23,25

General limitations inherent to telemedicine, including unequal access to reliable internet and smart devices, and concerns surrounding depersonalization of care and potential misinterpretation of clinical information, remain important considerations in the context of fertility care.22,28 Moreover, a fundamental constraint of telemedicine is the inability to perform thorough physical examination, such as pelvic and uterine inspection and assessment of fundal height and fetal movements, which are central to comprehensive patient evaluation and pregnancy monitoring. Additionally, there are concerns regarding data security and patient confidentiality of sensitive patient information shared across digital platforms.25

ANevertheless, as telemedicine technologies continue to evolve, these challenges can be addressed and should not diminish the considerable benefits.

Clinical Implications and Future Directions

Clinically, these technologies have the potential to shift fertility care toward a more individualized approach to embryo selection, treatment planning, and patient outcomes. While AI-directed, genetic, and telemedicine-based fertility care show significant promise, privacy concerns, limited clinical validation, and unequal access to online resources continue to limit the benefits.12,22,25 Increasing insurance coverage, expanding telehealth infrastructure, and developing cost-effective AI and genetic testing platforms will be critical to ensuring equitable access in the future. Despite very promising preliminary data, further large-scale, diverse studies are needed to validate these technologies and ensure their benefits are accessible across socioeconomic groups.

Beyond current AI, genetic, and telemedicine approaches, fertility care continues to evolve. Emerging technologies in stem cell research including ovarian tissue reconstruction29 and in-vitro gametogenesis,30 offer innovative directions that could revolutionize fertility care in the years to come. Advances in ovarian restoration offer potential for fertility preservation in patients undergoing or recovering from chemotherapy. Similarly, in-vitro gametogenesis shows promise for understanding pathogenetic mechanisms underlying conditions such as premature ovarian insufficiency or azoospermia.

Conclusion

Overall, this review highlights how advancements in AI, PGT, and telemedicine are reshaping fertility care by improving personalization, genetic risk stratification, and accessibility. AI offers more precise embryo and sperm selection, personalized ovarian stimulation protocols, and enhanced predictions of IVF success. Genetic testing, particularly through NGS and niPGT, has further enhanced embryo selection by screening for abnormalities and reducing genetic risk which has the potential to improve ART outcomes. Meanwhile, telemedicine has helped eliminate treatment delays and expand access to fertility specialists, thereby reducing geographic and socioeconomic barriers. Collectively, these technological advances are guiding fertility care toward increasingly precise and accessible approaches, with considerable potential to transform standards of care in reproductive medicine globally.



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