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Reproductive technologies in the digital age

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Genesis 1: 28- "God blessed them and said to them, be fruitful and increase in number, fill the earth and subdue it"

From the beginning of time it was ordained that we as humans should procreate and populate the earth. Fast forward to the 21st century—infertility has now become a major issue impacting both the female and male dyad. Many factors preclude to the increased incidence, among them:

a. **Infectious etiologies:** (chlamydia, gonorrhea, tuberculosis causing pelvic inflammatory disease and tubal scarring)

b. **Structural etiologies:** Polycystic ovarian disease, uterine malformations, uterine myomas, endometriosis

c. **Metabolic dysfunction:** Hypertension, diabetes, hypothyroidism

d. **Environmental toxins:** found in plastics, electronic devices, food packing, personal products and cleaning solutions contain endocrine disrupting chemicals which affect physiologic processes involved with fecundity

e. **Illicit substance abuse:** Drugs, alcohol, smoking – can impact both female and male fertility – abnormal sperm morphology/movement, low sperm count, impairment of fallopian tube function

f. **Unexplained:** After all factors have been explored, the etiology is considered as unexplained.

While infertility treatments like IVF, uterine transplants, ICSI have become big business, most health plans don't cover these reproductive technologies. Without health plans assisting in price negotiation, treatment costs can be astronomical, averaging 25K per IVF round. For a couple or woman embarking on such a journey, they have to contend with a fragmented formidable arena, often with a paucity of comprehension as to which fertility services are best for them. Into this milieu of expense, digital tools may have an opportunity to make the process easier, more informative, and perhaps more affordable.

Health care is progressively being delivered via digital channels such as the internet, social media, mobile technology telemedicine, video messaging and apps. The movement has been facilitated by the dissemination of mobile technology and the rapid developments of artificial intelligence. Digitization offers wide coverage, messaging which can be targeted to specific groups of consumers and offers marked potential for enhancing the delivery of sexual and reproductive health/rights (SRHR), information and support. Recent advances in the SRHR arena include the provision of online testing for sexually transmitted diseases, the use of which has made a significant impact in diagnosis and treatments. Telemedicine within this SRHR subset has additionally been an important adjunct in overcoming social, behavioral and geographic barriers to accessing services and facilitation of self-use of products and services. Digitization may additionally provide options that can transform the narrative for infertility evaluation.

Here are some pertinent examples:

Progeny—this platform exists which assists consumers by offering a shopping experience – for IVF, egg freezing, adoption, surrogacy and infertility benefits—by connecting then directly to specialists within the reproductive technology arena.

Multiple fertility apps are in existence, (example- **CLUE, FLO, and GLOW**) to help with fertility by allowing the woman to track basal body temperature for ovulation and best times for coitus. While the number of apps exist which cater to women there additionally are smart phone utilization apps for men to have their semen analyzed. There is an app called **YO** which has a mini clip on microscope which users can attach to their phone, along with a collection tip, testing slide, plastic pipette and a special liquefying powder. It provides men an ideal methodology of evaluating their fertility status, via at home semen analysis, without going directly to the physician.

The development and advances of robotics and computer science have enhanced gynecologic surgeon's skills to achieve accuracy and precision in complex surgeries like myomectomies, surgical treatments for endometriosis, and uterine anomaly repairs. These newer minimally invasive procedures afford less down time for the patient, less in hospital time, reduce surgical trauma, /operative complications and potentially improve outcomes. For the surgeon it can potentially decrease operative time, and afford a surgical experience that from an ergonomic perspective is easier. More clinical trials and data is needed to address whether the effectiveness of robotics for reproductive surgery is superior over traditional surgical techniques.

Artificial intelligence has experienced rapid expansion over the past few years, transitioning from an experimental focus to being fully implemented in various aspects of medicine. Technological advances in algorithms and theories, data set and computer evolution have markedly contributed to quantum leaps in current AI applications—specifically the ability to allow computers to detect patterns from data sets and utilize this information to make predictions. AI has been utilized to a small extent in reproductive technologies. Recently AI has been utilized to potentially select and predict the specific sperm cells to improve success rate of fertilization, assess the quality of oocytes and embryos, and to establish a useful ART prediction model to portend a successful outcome.

While this technology is in its infancy, it has the potential to assist infertility patients on a major level; increasing pregnancy

rates, decrease medical resource utilization, and most importantly to reduce the financial burden of reproductive technologies. From a Reproductive Endocrinologist's viewpoint, an AI component with image analysis could reduce error, increase recognition efficiency of viable sperm/eggs/embryos, decrease manual classification workload by providing automatic classification.

Within the reproductive technology domain, challenges arise in determining the best way to implement AI in clinical work. There exists a paucity of data as these models are still mostly in the experimental or "black box" stage. There additionally exists ethical and legal risks which can lead to distrust among both patients and clinicians. The creation , oversight, validation and supervision of such programs in the arena also is a significant consideration—no such core tenets exist currently. Selection bias from sample collection also is a concern.

Despite the challenges, it is inevitable that the capabilities of digitization/AI in reproductive medicine will continue to expand and improve. The integration of these processes has immense potential as an invaluable adjunct to Reproductive Endocrinologists, ultimately aiding both them and the patients they serve by providing high quality health care more effectively, accurately, and cost effectively such that the infertile can "be fruitful and multiply".

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Conflicts of interest

The authors declare that they have no competing interests.

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