Gynetics

A bi-monthly column offering an informed insight into the latest cutting-edge advancements in gynecology and women's health by experts on women's reproductive health

AI Meets Omics

Transforming Fertility Preservation and Reproductive Longevity in BRCA Carriers

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For women carrying BRCA gene mutations, the struggle isn't only about cancer risk—it's also about time. BRCA mutations, particularly in (BRCA1), accelerate ovarian aging and reduce fertility years earlier than expected. With risk-reducing surgeries and chemotherapy often required before family building, many women face the loss of reproductive potential long before they're ready.

Today, two forces -- omics technologies and artificial intelligence (AI) are converging to change that story, turning fertility preservation into a more predictive, personalized, and preventive science.

The BRCA and Fertility Connection

The BRCA1 and BRCA2 genes encode DNA repair proteins essential for protecting oocytes from age-related damage. When these genes malfunction, ovarian cells accumulate genetic errors, leading to premature follicle loss, lower anti-Müllerian hormone (AMH) levels, and reduced oocyte yield during fertility treatments.

Meta-analyses show that BRCA1 carriers have a significantly diminished ovarian reserve, while BRCA2 carriers appear less affected. This means earlier reproductive decline and fewer available eggs for cryopreservation. For oncologists and fertility specialists, integrating early reproductive counseling into BRCA care is now essential.

The Omics: The Molecular Map of Ovarian Health

Omics refers to technologies that decode biological systems across multiple layers --- genomics, transcriptomics, proteomics, and metabolomics. Together, they give clinicians a panoramic view of ovarian function and reproductive aging.

- Genomics identifies the exact BRCA variant and associated risk of ovarian insufficiency, helping tailor preservation timing.
- Transcriptomics and proteomics reveal downstream stress and repair pathway changes in granulosa cell -- structure-critical supporters of oocyte health.
- Metabolomics, perhaps the most dynamic of all, maps small molecules such as amino acids and lipids within follicular fluid that directly correlate with oocyte competence and embryo quality.

Recent follicular-fluid profiling studies have linked higher levels of glutamine, arginine, IGF-1, and antioxidants with high-quality oocytes, while disrupted lipid and energy metabolism predict poorer outcomes. These discoveries bring molecular precision to fertility preservation, steering clinicians from reactive intervention toward proactive prediction.

Omics Biomarkers Shaping Preservation Protocols

Among the most influential omics-derived markers are AMH, antral follicle count (AFC), and BRCA genotyping, which collectively inform when and how to intervene.

Emerging gene variants in FSH receptor, NR5A1, and FIGLA are also being studied to fine-tune ovarian stimulation regimens. Multi-omics panels can now integrate AMH profiles with transcriptomic and

metabolomic data to model "ovarian age" more accurately than chronological age alone.

These insights are changing fertility preservation counseling

- Younger BRCA carriers may elect earlier oocyte cryopreservation even before cancer onset.
- Cancer survivors can pursue individualized ovarian stimulation cycles with letrozole-based, estrogen-sparing protocols guided by omics and hormonal data.
- AI-assisted embryo screening can identify BRCA-free embryos during IVF using patterns extracted from time-lapse imaging, genomic sequencing and genetic testing (PGT-M)

AI: Turning Data into Personalized Decisions

If omics provide the data, AI provides direction. Machine learning models analyze massive datasets—combining genetics, hormone levels, imaging, and even lifestyle factors to predict ovarian performance with remarkable accuracy.

Recent platforms now deploy AI algorithms to forecast oocyte yield before stimulation, anticipate the best drug protocol, and simulate outcomes across multiple cycles. In embryo selection, AI-enhanced image recognition systems rank embryos by developmental potential, reducing human bias and improve success rates.

Beyond embryology, AI-driven multi-omics integration is helping identify BRCA-related ovarian aging pathways and potential therapeutic targets, offering new possibilities for cryoprotection of ovarian tissue.

The result is a shift from one-size-fits-all fertility preservation to precision medicine, where each BRCA carrier's plan is data-modeled, risk-adjusted, and dynamically personalized.

Safety and Success: The Data Reassurance

For many BRCA carriers and survivors, safety is the foremost concern—will hormonal stimulation or ART trigger recurrence?

A global 2024–2025 study across BRCA-positive women offered reassurance: recurrence rates were similar or lower in those conceiving with ART (12.1%) compared to natural conception (27.1%).

Moreover, live birth rates exceeded 80% in both groups, and obstetric outcomes were also comparable.

Preimplantation genetic testing (PGT-M) has further improved reproductive safety, ensuring carriers can avoid passing mutations while maintaining high pregnancy success rates.

These findings underscore that modern ART—when guided by tailored omics and AI support is both oncologically safe and reproductively effective.

Patient-Centered Fertility Counseling

Omics-guided fertility preservation isn't only scientific—it's deeply personal. Women should be counseled about:

- Reduced ovarian reserve risks in BRCA carriers
- Optimal timing for cryopreservation before cancer therapy
- PGT-M options to prevent mutation transmission to offsprings
- Realistic oocyte yield expectations, modeled using omics profiles
- Emotional readiness and genetic implications for early screenings and family planning.
- In the UAE, fertility preservation for women carrying BRCA mutations is now officially recognized under the Thiqa insurance framework, which covers oocyte and embryo cryopreservation before oncologic or risk-reducing treatment, making advanced fertility protection more accessible.

Such discussions are most valuable when delivered by multidisciplinary teams: reproductive specialists, oncologists, and genetic counselors—supported by AI-based decision tools for individualized recommendations.

Predictive Fertility Medicine towards Longevity

The next decade will see fusion between AI, omics, and wearable biosensors, creating real-time fertility monitoring systems.

Imagine a "Reproductive Aging Dashboard" where BRCA carriers can track ovarian health via digitized biomarkers, modeled continuously against global datasets. Multi-omic fertility passports and organoid-based testing may one day predict ovarian decline years in advance, redefining the very concept of fertility preservation. This convergence of disciplines heralds more than technological progress; it represents hope.

For women born with BRCA mutations, science is finally learning not only to protect life from cancer but also to preserve the possibility of creating it. H