

Back to the FUTURE

BY RANYA HABASH, MD

Get ready for digital twinning and generative AI to transform precision medicine.



Precision medicine has emerged as a cornerstone of modern health care. It promises a future when treatments are meticulously tailored to individual patients. Groundbreaking technologies fueled by digital twinning, predictive analytics, and generative AI could revolutionize the way we approach medicine. These data-driven solutions have already transformed other industries.

DEFINING THE CORE TECHNOLOGIES

Digital twinning. This concept originates from fields as diverse as manufacturing and finance. *Digital twinning* refers to the creation of a virtual, dynamic replica of a physical entity or system. In the context of precision medicine, the entity is the patient.

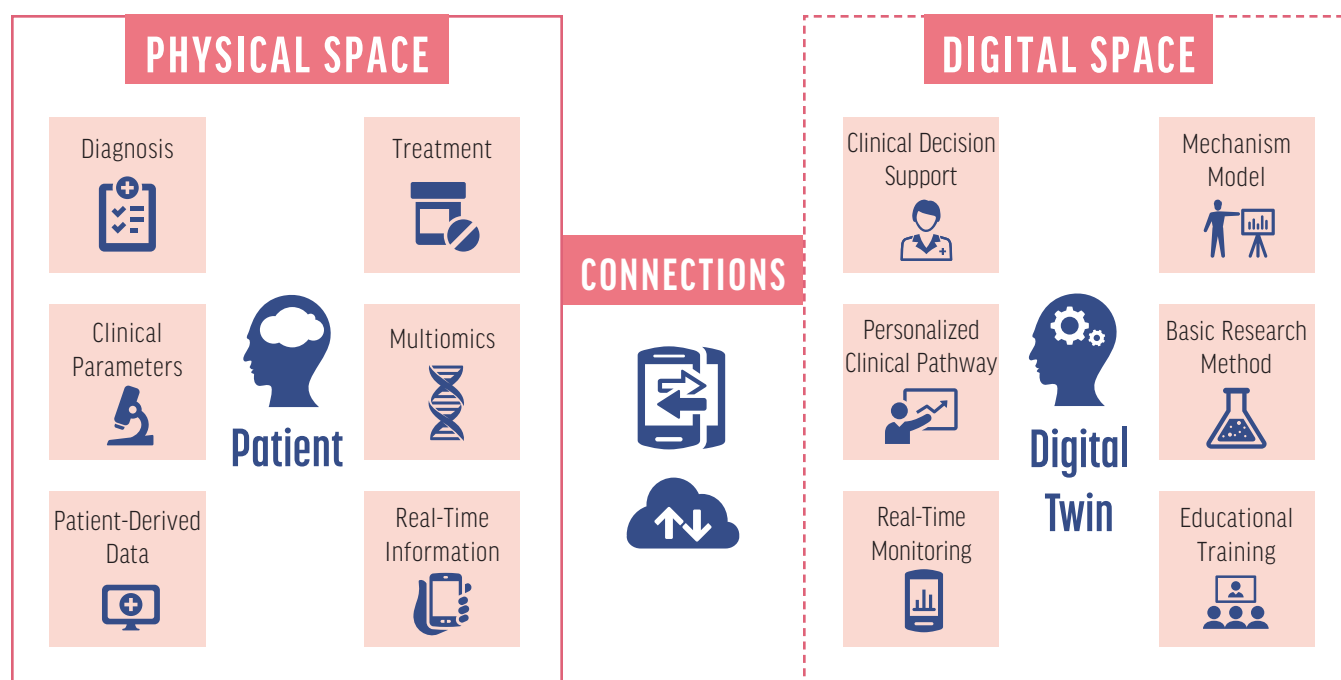


Figure. Potential applications of digital twin modeling in medicine.

Adapted from Sun T, He X, Li Z. Digital twin in healthcare: recent updates and challenges. *Digit Health*. 2023;9:20552076221149651.

A digital twin aggregates vast amounts of patient-specific data from disparate sources ranging from electronic health records and genomic data to lifestyle information and data from connective devices. This coalescence of data forms a dynamic, virtual model of a patient's health status, enabling a level of monitoring and analysis that was previously unachievable.

Predictive analytics. Powered by machine learning and advanced statistical methodologies, predictive analytics forms another pillar of data-driven solutions. It harnesses large datasets to forecast future outcomes, thereby offering a new level of insight into a patient's health trajectory. When combined with the rich data of a digital twin, predictive analytics helps physicians anticipate health risks, detect early disease, optimize treatments, and improve patient outcomes.

Significant advantages of predictive analytics for precision medicine are early detection and disease prevention. Early detection of conditions, especially those with silent or insidious onset such as glaucoma and macular degeneration, is critical to slowing or stopping irreversible damage and vision loss and optimizing patient outcomes. Coupled with a digital twin model, predictive analytics provides a comprehensive, real-time snapshot of a patient's health, which in turn helps identify subtle physiologic changes that may indicate the early stages of a disease. These changes, when analyzed, can provide the warnings we need to intervene quickly.

Generative AI. By leveraging deep learning architectures, generative AI can simulate complex systems and generate new data that mirror the original dataset. In the context of digital twins, generative AI models could simulate a patient's physiologic response to different treatments under different conditions. The information could help identify the most effective and personalized therapeutic approach.

For glaucoma and macular degeneration, for example, a patient's digital twin, equipped with generative AI, could analyze comprehensive risk factors such as age, family history, lifestyle traits, and genetics to forecast the risk of disease and its progression. This knowledge could prompt lifestyle modifications or formulation of a treatment plan that might halt irreversible damage before it even starts. As another example, generative AI could run simulations on the digital twin of a cancer patient to model a tumor's likely response to different chemotherapy regimens. It could even predict the risk of metastasis.

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CONCLUSION

Precision medicine with digital twinning, predictive analytics, and generative AI heralds a massive paradigm shift in health care. Simulations of future health states with data-driven solutions have the potential to enhance early detection, risk stratification, and disease prevention. Leveraging such insights to modify lifestyle and treatment plans could revolutionize patient care. As we embrace precision medicine

technologies, we create a world where each person's unique health needs are understood, anticipated, and addressed early, helping us change tomorrow's outcomes today—by going back to the future. ■

RANYA HABASH, MD

■ Voluntary Assistant Professor of Ophthalmology, Bascom Palmer Eye Institute, University of Miami Miller School of Medicine, Florida

- Visionary Innovation Mentor and Mentor, Clinical Informatics Management Program, Stanford University School of Medicine, Palo Alto, California
- Cofounder, MetaMed
- FDA Digital Health Network of Experts
- Cochair, Artificial Intelligence, American-European Congress of Ophthalmic Surgery
- ranya@habash.net
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