THE JOB SEARCH ISSUE

DEPARTMENTS

Tech Notes

Digital twins

How virtual models are being used to improve health care.

MICHELE MEYER

COULD DIGITAL TWINS REVOLUTIONIZE HEALTH CARE? That remains to be seen, but the prospect is tantalizing—and galvanizing—for the medical community.

Digital twins are virtual models of individual patients' bodies or organs, which can take personalized medicine to a new level. These replicas combine information from computer simulations, artificial intelligence, real-time sensor data, patient history, electronic health records and disease registries to reduce guesswork in cardiology, oncology, obstetrics and other health care areas.

Such computer simulations can help predict an individual's disease progression, titrate their medicine or even test treatment alternatives before a surgeon lifts a scalpel or an oncologist considers chemotherapy options.

"Digital twins can be personalized in many ways," says Jun Deng, Ph.D., professor of therapeutic radiology, biomedical informatics and data science at Yale School of Medicine. "They can help predict outcomes and adverse effects and can provide many treatment options for the patient and physician to decide what works best for them."

And they're just getting started in the field of medicine. The global digital twins health care market was valued at $1.6 billion in 2023 and could reach $21.1 billion by 2028, according to MarketsandMarkets, an international research firm specializing in artificial intelligence.

Medicine is catching up

While relatively new for medicine, digital twins have long been used in urban planning, construction and automaking, after getting their start in the 1960s as tools for NASA's Apollo moon-landing program.

NASA simulators first trained astronauts and mission controllers to face a variety of possible situations and problems. Then they were needed in a real-time crisis, when an explosion crippled the Apollo 13 spacecraft en route to the moon in 1970.

NASA quickly used simulators controlled by a network of then-advanced digital computers to speedily diagnose and respond to the crisis. Safely bringing three astronauts home would not have been possible without nascent digital twin technology.

As for automakers, "Car designers realized that if you used a computer, you could experiment with different shapes of car parts and see how they fit together or how they could break down," says Kristin M. Myers, associate professor of mechanical engineering at Columbia University in New York, who learned about digital twins while training to be a mechanical engineer as a student intern for General Motors. "That was so much better than the clay models that had been around forever and were so time consuming."

Now, she uses ultrasound to create 3-D computational models of women's uteruses and cervixes to help predict a pregnancy's duration and reduce the frequency of premature births. These models can show how much load is on the uterus and the cervix and what might lead to a preterm birth.

"No two women are alike," she says. "Computer replicas of individuals can give mothers and their OB/GYNs intel about their pregnancy and the likelihood of a full-term birth, due to the infant's growth in the womb, the hospitability of the uterus, the strength of the cervix and the size of a uterus."

Beating cancer with predictive twins

Cancer treatments also are getting digital-twin boosts.

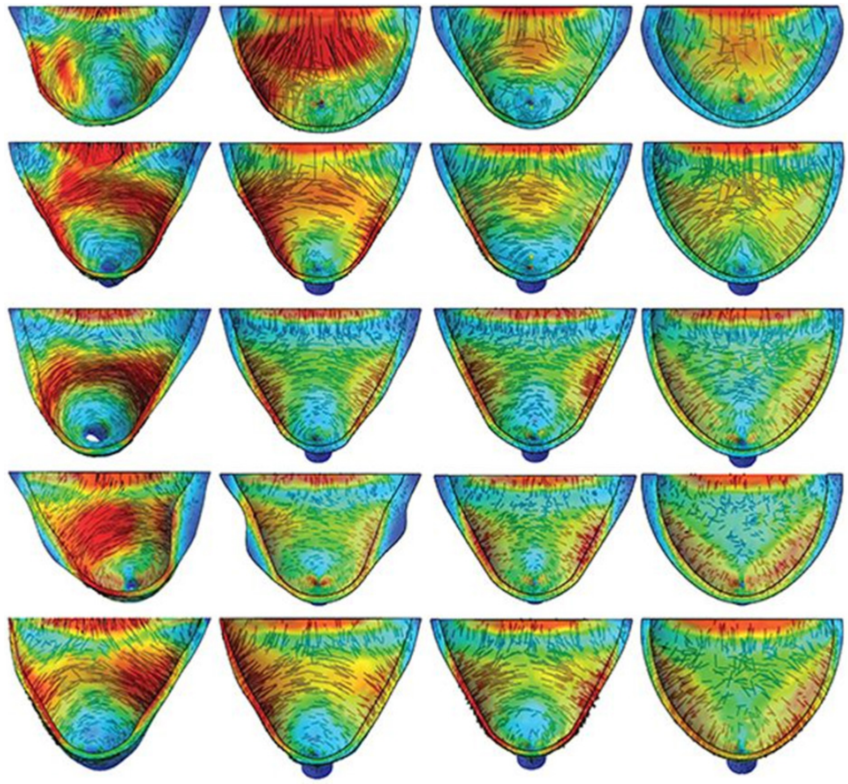
Digital twins enable researchers and physicians to recreate individual patients' body parts to better diagnose the disease, predict its progression, determine how a patient will react to treatment, pinpoint the most effective medicines and convey the best surgical options.

"Cancer radiotherapy requires math, physics, medicine, modeling, engineering and optimization to personalize a plan for a cancer patient," Deng says.

"Currently, we apply the same strategy to each cancer patient. They come in every day, and physicians evaluate its effectiveness after their course of treatment. That means five to seven weeks later, which is not optimal. ...You don't want to wait seven weeks to say radiation hasn't eradicated the tumor."

While radiation oncologists already have image-guided radiation therapy, they need to know more, he says.

"That's where digital twins come into play. You want to build a virtual model for each patient, feeding real-time data into the model to achieve a faster, more personalized and more accurate timeline," Deng says. "That provides treatment options without having to wait seven weeks to see if it worked."



▲ Digital twins can help physicians understand how patients might react to treatment options, such as these images of uteruses developed to determine early-labor risks. Image courtesy of Kristin Myers.

Cardiology also benefits

Cardiologists even can test different surgeries on a digital twin to determine what would provide the best outcome for a heart patient.

"You can build a digital twin for a patient's heart, then apply patient data in real time to simulate a what-if scenario," Deng says. "That's the power of digital twins."

At Johns Hopkins School of Medicine in Baltimore, digital twins are predicting electrical activity in the heart for patients with arrhythmia and other heart rhythm disorders.

"Cardiologists can simulate a heartbeat in the digital twin and poke and prod it with small electrical signals to see what happens," Myers says. "By mirroring the structure, damage, inflammation and electrical activity of a patient's heart, they can determine the most likely progression of a disease and the best treatment."

But even with such advances, "so much more in medicine could benefit from digital twins," she says.

For example, she says, "wouldn't it be nice to test a hip implant's fit and durability on a computer first, or determine how well an amputee's prosthesis would move and how much pressure it would put on the arm?"

Dentists already use digital twins

for cracked molars. After scanning the mouth, they make a virtual model of the molar to make a new one that will fit exactly.

"Digital replicas already are in our everyday life," Myers says. "But much of the body is soft, with blood pumping. A lot of research is needed to represent it accurately on computers with a computational model.

Challenges remain

Indeed, implementing digital twins in medicine and health care involves many challenges.

First is data integration. Data is stored in different systems in different formats, and it's challenging to integrate them for a particular patient.

Second is building a virtual model that will mimic the patient at a microscopic or macroscopic level, depending on specific needs, Deng says.

Third is model validity. "How do you know your model's predictions are correct?" he says.

Concerns also include issues of privacy, ownership of the digital twin and the potential for misuse and insurance denial.

The future for digital twins

"I don't think digital twins have made it yet in medicine's mainstream, even in cardiology and orthopedics," Myers says. "But if we work together and collaborate, I hope that in five to 10 years we'll see a whole digital twin body developed and employed in medicine."

Deng believes digital twins "could help all kinds of medical specialties. But that's down the line."

"It's much more complicated than it sounds," Myers says "The human body is complex. There are so many things that we still don't know." •