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For Immediate Release

Researchers Create Realistic 3D Organ Model to Plan Surgery

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What if a surgical model not only could mimic the look and feel of a patient's organ but also give surgeons quantitative feedback as they use it to practice the procedure? A team of scientists in the McAlpine Research Group at the University of Minnesota have been trying to answer this question, creating a prostate model that accomplishes exactly that.

In their article for the *Annual Review of Analytical Chemistry*, titled "3D Printed Organ Models for Surgical Applications," Kaiyan Qiu, Ghazaleh Haghiashtiani, and Michael C. McAlpine from the University of Minnesota, review current materials used in 3D printed patient-specific organ models used in surgical pre-planning, as well as the state-of-the-art materials and techniques that allow them to replicate many kinds of human tissue.

The use of 3D models in medicine and anatomy is not new. Centuries ago, they were fashioned out of clay, wax, wood, glass, plaster, or even ivory, and they served as teaching tools or as illustrations of the mechanisms of disease, without having to resort to human dissection.

More recently, the boom in 3D printing technology has allowed medical professionals to visualize organs that might require surgery. Using data collected with imaging techniques such as CT scans, MRIs, or ultrasounds, these models can be fabricated to the exact specifications of an individual's organ.

This is of vital importance. A recent study has shown that an average of more than 250,000 people die each year in the United States as a result of medical errors, including more than 4,000 "never events" in surgery — events that should never have happened. Although complete elimination of errors is impossible, proper surgical planning and rehearsal can be key to reducing their occurrence. Model organs are quickly becoming invaluable tools to help prepare for surgery, not just allowing doctors to get a better feel for the organ on which they must operate, but also letting them plan the procedure. Recently, a 3D printed model of a patient's hip joint changed the surgical team's minds about the best treatment plan and resulted in performing a hip replacement instead of reconstruction of the damaged hip joint.

Current materials used in 3D printing have limitations, however. Compared to 2D slices of MRI or CT scans, 3D hard plastic models have helped increase the accuracy of surgeons by helping them to visualize the organ. They can also help inform the patients about their conditions and show inexperienced surgeons what to expect from the operation. Their main flaw, of course, is that they are not pliable enough to allow for surgical rehearsal. In contrast, rubber-like materials can provide a tactile feel closer to the actual organ they are meant to model and allow for cutting and suturing, but their properties do not precisely match those of an actual organ in elasticity, hardness, or color.

"These present the correct anatomy, but they're incapable of providing quantitative feedback or even accurate tactile sensation," said Kaiyan Qiu, a postdoctoral researcher in the McAlpine group and lead author of the article. "Surgeons often can't apply their medical tools into the inner channels of the models, and when they do, they don't know if they're applying too much pressure on the organ."

To remedy this, co-authors Dr. Qiu, Michael McAlpine, who leads the group, Ghazaleh Haghiashtiani, a PhD candidate, and their team have developed silicone-based 3D printing materials, or "inks," that can be finely tuned to mimic these properties. Using a customized direct-write assembly 3D printer with a fine nozzle, they were able to construct a prostate model whose dimensions were obtained with MRI imaging and whose physical properties were established by mechanical tests on actual patient prostate samples, which informed their inks.

"We tried different polymers until we finalized the recipe," said Dr. Qiu. "We are now able to accurately mimic most kinds of human tissue."

Once they created the model, they had to make sure it behaved as closely as possible to the patient's prostate. They first tested individual inks after printing by contrasting them with the biopsied tissue. Then they verified the anatomical fidelity of the 3D printed model by scanning it with an MRI and matching the results to those of the patient's organ by doing a surface comparison.

"With these data, we now had a way to compare the physical behaviors of the two by doing a computer simulation on the patient's organ and an actual experiment on our 3D printed model," Ms. Haghiashtiani explained. "We wanted to make sure that our organ model behaved like the real thing."

They were also able to print and integrate electronic sensors onto and within the model that, when connected to a computer, provided quantitative feedback. This capability could enhance surgical precision in an actual procedure, as well as help train surgeons for steadiness, flexibility, and dexterity, just like a high-tech game of "Operation," where a loud buzz goes off every time the player is too heavy-handed.

"When surgeons practice using different surgical tools, they can know how much force to apply as they get real-time feedback," said Dr. Qiu. "They can adjust it and use that knowledge in real surgery to avoid damaging tissue."

They're not stopping there, setting their sights on more complex 3D models. Some could account for different types of tissue simultaneously printed with different inks. "We could replicate cancerous tissue and healthy tissue within the same model," says Ms. Haghiashtiani. Another direction is to develop dynamic models, such as a 3D printed heart that can beat like a real one. A third idea is to create models that integrate sensors capable of taking various types of measurements at once, like temperature and multidirectional pressure.

Ultimately, they say, it is possible that their models could replace real organs.

"We are also working on bioprinting, where we can print organs that can replicate biological functions," said Dr. Qiu.

"If we could get to this point, if we have the technology, you could say 'why not use this for transplants?'" added Ms. Haghiashtiani.

Read more about prior limitations, current progress, and future perspectives in this important area in their *Annual Review of Analytical Chemistry* article.

The ***Annual Review of Analytical Chemistry***, first published in 2008, provides a perspective on the field of analytical chemistry. The journal draws from disciplines as diverse as biology, physics, and engineering, with analytical chemistry as the unifying theme.

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