AUTONOMOUS ROBOTS IN THE O.R.

Scientists are developing machines that perform surgical tasks with little oversight from humans

By Sara Castellanos

Researchers at Intel Corp. and the National University of Singapore, co-led by Dr. Benjamin Tee, right, are developing 'artificial skin' for a robotic finger, left. It is designed to mimic the sense of touch.

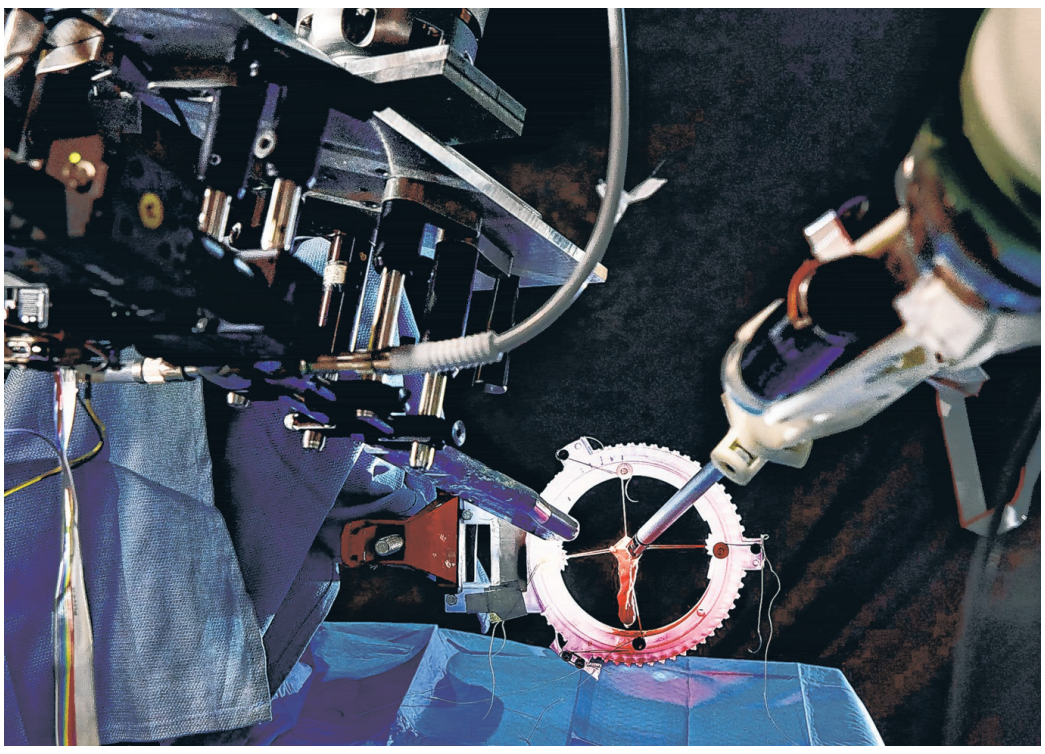
Benjamin Tee has long been captivated by a scene in "Star Wars: The Empire Strikes Back" where the surgical droid 2-1B replaces Luke Skywalker's hand after Darth Vader slices it off with a lightsaber in a battle on Cloud City.

A fully autonomous robot surgeon is the Holy Grail—and many years off, says Dr. Tee, assistant professor of materials science and engineering at the National University of Singapore. He and other researchers are developing devices that can perform surgical tasks with minimal human oversight.

Dr. Tee's latest project is an "artificial skin" that would give robots a sense of touch, allowing them to do things like differentiate between healthy tissue and tumors and make surgical incisions. Other researchers are working on robots that stitch up incisions and navigate to repair organs.

Today, surgeons use million-dollar robotic devices such as Intuitive Surgical Inc.'s da Vinci robot in operations that require more precision, range of motion and control than they might get by using their own hands. Each movement of the surgeon's hands directs the robot's arms, which hold the surgical instruments. The next frontier is to build devices that function autonomously—a critical feature for operations performed outside in Antarctica, in rural areas without access to surgeons or, one day, on a spacecraft.

Automating mundane and repetitive tasks, such as suturing, could allow surgeons to focus on more critical and complex parts of operations and minimize the mental and physical fatigue associated with hourslong procedures. The U.S. has a worsening shortage of surgeons, with an expected shortfall of as many as 28,700 by 2033, according to the Association of American Medical Colleges. The coronavirus pandemic also highlighted the need for robot help in operating rooms to minimize the risk of exposure to the virus for staff and patients.



▲ The Smart Tissue Autonomous Robot, above, can conduct a challenging step of colon surgery on its own. Researchers at Children's National Hospital and Johns Hopkins University are testing its suturing capabilities on pig intestine.

28,700

The projected shortfall of surgeons by 2033

There are technical, regulatory and safety hurdles. The algorithms underlying the robots need to be tested for accuracy. The U.S. Food and Drug Administration, which clears most medical devices, hasn't yet approved an autonomous surgical robot. The machines would need to account for differences in anatomy or react appropriately to complications that come up during surgery, which can be unpredictable. Intuitive Surgical says it has no plans to develop robots that perform surgical tasks autonomously, in part because of a lack of demand.

Still, early signs show that robots could eventually perform certain surgical procedures quickly and more consistently than humans, which could minimize complications. "That's something where the robot really shines—precision, repeatability," says Axel Krieger, assistant professor in the Department of Mechanical Engineering at Johns Hopkins University, who is researching autonomous surgery. "And it doesn't get tired."

Here are three examples of current research projects in robotic surgery.

Artificial skin

Surgeons depend on their sense of touch to identify organs, cut tissue and tumors, and apply the right amount of force, says Khek-Yu Ho, a doctor and director of the Centre for Innovation in Healthcare at the National University Health System in Singapore. Researchers from the National University of Singapore and Intel Corp. are attempting to mimic that sense of touch with a robotic silicon finger.

The device has about 100 sensors per square centimeter, with data running through a single wire connected to a neuromorphic chip, a type of computer chip that allows AI models to be trained using a fraction of the data of traditional computer chips. In early tests this year, the finger was able to tell which of two similarly shaped objects was softer, about 10 times faster than the blink of an eye, says Dr. Tee. In the next decade, the technology could be incorporated into a haptic glove—which uses force, vibration and motion to simulate the feeling of a virtual object—so that surgeons could perform operations remotely and feel what the robot feels.

Surgical sutures

Researchers from Children's National Hospital in Washington, D.C., and Johns Hopkins, including Dr. Krieger, are developing a robot capable of conducting a colon anastomosis on its own. An anastomosis refers to the closing up of a tubular structure, and is normally done by suturing, or stitching, the tissue back together. Reattaching a healthy colon requires about 15 to 20 stitches. If even one stitch is too loose, the patient risks an anastomosis leak, which can cause a deadly infection; consistent, high-quality sutures could reduce such complications.

The Smart Tissue Autonomous Robot, or STAR, uses a motorized robotic suturing tool that rotates the needle through the colon tissue automatically. STAR is powered in part by machine learning, which is used in detecting tissue motion. This way, the robot can recognize the patient's breathing and apply the suture at the correct point. In theory, the robot could achieve a level of consistency in the spacing and tension of the sutures beyond what humans can accomplish.

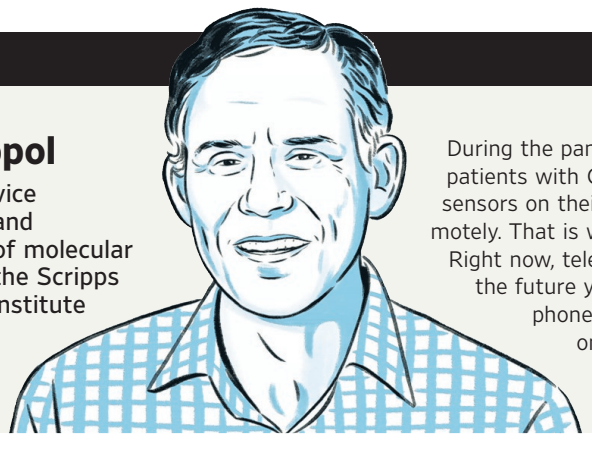
Robotic catheters

To minimize risks and recovery time for patients, cardiologists typically prefer to use a catheter—a thin, flexible tube that is inserted through an arm, groin, thigh or neck—to get access to the heart, rather than cutting open a person's chest. But navigating with a catheter to the right part of the heart is tricky work. A team led by Pierre Dupont, chief of pediatric cardiac bioengineering at Boston Children's Hospital and professor of surgery at Harvard Medical School, has developed a robotic catheter that would navigate on its own. In an experiment that concluded in 2019, the robotic catheter was able to help with leaks that sometimes happen after valve replacements.

The catheter navigates using a haptic vision sensor, in which images from a tiny camera are combined with machine-learning algorithms that can tell whether the catheter tip is touching blood, tissue or valve. After the catheter arrives at the repair site, the surgeon takes over and patches up the leak with an occluder, which resembles a small metal plug. Automating the navigation would free up the surgeon to focus on deploying the occluder and optimizing the valve repair, much like a fighter pilot on a mission, Dr. Dupont says. The pilot "is doing all of the higher-level mission planning work," he says. "The plane is in autopilot." Dr. Dupont and his team are currently researching ways for robotic catheters to help with more complex valve repairs.

Bottom right: A closeup of a silicone sheet embedded with electronic conductors for tactile sensors at the National University of Singapore. ▼

CLOCKWISE FROM TOP LEFT: ORE HUIYING FOR THE WALL STREET JOURNAL (3); MAX AGUILERA-HELLWEG FOR THE WALL STREET JOURNAL; ILLUSTRATION BY KYLE HILTON



Eric Topol

executive vice president and professor of molecular medicine, the Scripps Research Institute

During the pandemic, several health systems have kept patients with Covid-19 at home and monitored them with sensors on their arms where they can track them remotely. That is where we're headed.

Right now, telemedicine is kind of like version 1.0, but in the future you may actually be able to take your smartphone, pop in a probe, and do an ultrasound exam on any part of your body except your brain.

There will be a shift to more patient autonomy where they will have the technology to generate and interpret their own health data, while reserving in-person doctor visits for serious matters like a new diagnosis or a threatening condition.

The biggest opportunity would be having a virtual medical assistant where a person has all their health records continually updated seamlessly from the time they are in the womb until the present. Not only that, but it integrates their genome, their microbiome, their environmental sensors and up-to-date literature on any risks and provides feedback to the patient to prevent provoking a condition. ▶▶