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Brain surgery by autonomous robot? It’s possible — and could save lives

Hundreds of people in the United States die every day from thromboses — blood clots of veins or arteries. In many cases, blood clots are a normal part of healing. But these coagulated masses of blood cells that form inside veins and arteries can also obstruct circulation, become dislodged and cause strokes and heart attacks.

Many of these sometimes deadly outcomes can be avoided with access to rapid intervention and advanced surgical expertise. However, many Americans live too far from hospitals that can perform time-sensitive and highly technical thrombectomies: only 12% receive the lifesaving treatment, out of hundreds of thousands of eligible stroke patients annually. Unfortunately, delays in receiving treatment raise the risk of serious long-term disability or death, and can add hundreds of thousands of dollars to healthcare costs.

But what if it were possible to bring life-saving thrombectomies to hospitals throughout the country so that every person in the U.S. had access to this care? That’s what UC Santa Barbara mechanical engineer Elliot Hawkes is aiming to do. With a grant from the federal government’s Advanced Projects Research Agency for Health’s (ARPA-H) Autonomous Interventions and Robotics (AIR) program, Hawkes and collaborators from lead institution UC San Diego —plus Stanford University, Vanderbilt University, University of North Carolina at Chapel Hill, University of Missouri-Kansas City and industry partners EndoTheia, Vine Medical, and GE Healthcare — are working to bring soft robotics to cardiovascular surgery, with a

method that combines maximum precision with minimal harm.

“We’re betting on a robot that can do this difficult, life-saving procedure but can’t hurt you,” Hawkes said.

First do no harm

A thrombectomy is a highly technical and time-sensitive procedure that requires locating and carefully removing clots that block the vital flow of blood to the brain and other organs. In some cases, the the surgeon opens a blood vessel to remove the offending clot and then closes the vessel again. In other cases, the procedure is less invasive, utilizing devices that are introduced via catheters into the blood vessel to break up the clot and suction it away. In both scenarios, these procedures are performed by surgeons with years of specialized training.

“If done relatively soon, the surgery can basically reperfuse the brain,” Hawkes said. “It’s an amazing procedure, but not that many people have access to it, and it’s a very hard surgery to do.” There also aren’t enough surgeons to meet the demand for the procedure, he added. The vision of the ARPA-H AIR program was to explore autonomous systems that might be able to execute the procedure without the presence of a highly trained surgeon — systems that could be deployed in hospitals across the country in order to address the time-critical nature of the surgery.

A common and logical approach to the challenge would be to create and train an automaton that would wield existing surgical technology and techniques. The careful removal of the clot would all be more or less the same as in conventional thrombectomies, only replacing the human surgeon with an AI-enabled robot surgeon.

However, training a robot surgeon to do the same things human surgeons have taken years to do safely did not seem feasible in the roughly five years the team was given by ARPA-H to build and test a robotic system, Hawkes said.

“If you have a tool that is relatively rigid and could puncture the blood vessel if steered the wrong way, it could cause a worse problem than the patient already has,” he said. Any errors in the autonomy, even the idiosyncrasies of the patient’s anatomy, could lead to unforeseen problems during the procedure, he added. “Our take was, let’s actually reinvent the tools that are going inside the body.”

Enter the Hawkes Lab's soft, vine-like robot. Mimicking the way vines grow to move through a space, the soft tube-shaped robot everts from its tip when pressurized while the rest of the body stays stationary. Tip extension has its advantages: for one thing, it minimizes friction and force, as opposed to a catheter or other instrument being pushed from its base through a blood vessel. Additionally, the softness of the robot and the steering from the tip enables the robot to follow complex, tortuous paths while being compliant with the blood vessel. Once at its destination the robot can then deploy the appropriate tools to deal with the clot.

"What's nice about that is that it's safe by physics rather than by AI," Hawkes said.

Artificial intelligence, however, will be fundamental to the autonomy of the robot, from developing a patient-specific optimized plan to enabling the robot to make the many decisions to execute its actions throughout the procedure.

The challenge for Hawkes and his colleagues on the hardware side will be miniaturizing the technology down to the scale required to insert it into blood vessels. Hawkes has long envisioned the potential for soft, growing robots in a variety of applications, from search and rescue to medicine.

The robot will be subject to a two-year milestone check and a capstone demonstration at the end of the fifth year. From there the robot could conceivably make the jump from research investigation to clinical testing. "Shortly thereafter we could move forward and try to actually get into the clinic with live people," Hawkes said.

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