New flexible, steerable device placed in live brains by minimally invasive robot

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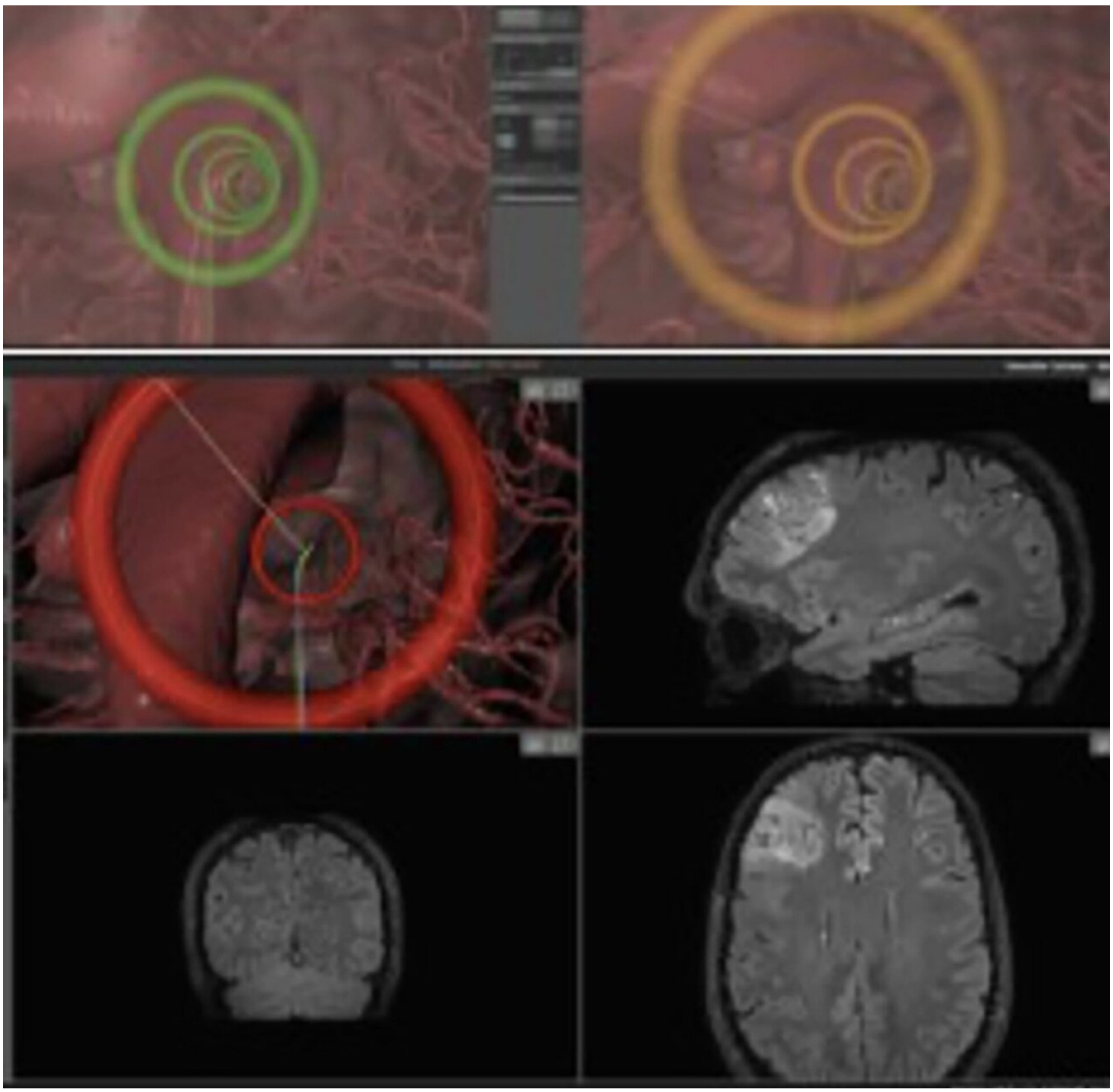

The surgeon's view of the catheter in the brain. Credit: *PLOS ONE* (2022). DOI: 10.1371/journal.pone.0275686

Imperial College London scientists have successfully placed a bioinspired steerable catheter into the brain of an animal for the first time.

The early-stage research tested the delivery and safety of the new implantable catheter design in two sheep to determine its potential for use in diagnosing and treating diseases in the brain.

If proven effective and safe for use in people, the platform could simplify and reduce the risks associated with diagnosing and treating disease in the deep, delicate recesses of the brain.

It could help surgeons to see deeper into the brain to diagnose disease, deliver treatment like drugs and laser ablation more precisely to tumors, and better deploy electrodes for deep brain stimulation in conditions such as Parkinson's and epilepsy.

Senior author Professor Ferdinando Rodriguez y Baena, of Imperial's Department of Mechanical Engineering, led the European effort and says that "the brain is a fragile, complex web of tightly packed nerve cells that each have their part to play. When disease arises, we want to be able to navigate this delicate environment to precisely target those areas without harming healthy cells."

"Our new precise, minimally invasive platform improves on currently available technology and could enhance our ability to safely and effectively diagnose and treat diseases in people, if proven to be safe and effective."

Developed as part of the Enhanced Delivery Ecosystem for Neurosurgery in 2020 (EDEN2020) project, the findings are published in *PLOS ONE*.

The platform improves on existing minimally invasive, or "keyhole," surgery, where surgeons deploy tiny cameras and catheters through small incisions in the body.

It includes a soft, flexible catheter to avoid damaging brain tissue while delivering treatment, and an artificial intelligence (AI)-enabled robotic arm to help surgeons navigate the catheter through brain tissue.

Inspired by the organs used by parasitic wasps to stealthily lay eggs in tree bark, the catheter consists of four interlocking segments that slide over one another to allow for flexible navigation.

It connects to a robotic platform that combines human input and machine learning to carefully steer the catheter to the disease site. Surgeons then deliver optical fibers via the catheter so they can see and navigate the tip along brain tissue via joystick control.

The AI platform learns from the surgeon's input and contact forces within brain tissues to guide the catheter with pinpoint accuracy.

Compared to traditional "open" surgical techniques, the new approach could eventually help to reduce tissue damage during surgery, and improve patient recovery times and length of post-operative hospital stays.

While performing minimally invasive surgery on the brain, surgeons use deeply penetrating catheters to diagnose and treat disease. However, currently used catheters are rigid and difficult to place precisely without the aid of robotic navigational tools. The inflexibility of the catheters combined with the intricate, delicate structure of the brain means catheters can be difficult to place precisely, which brings risks to this type of surgery.

To test their platform, the researchers deployed the catheter in the brains of two live sheep at the University of Milan's Veterinary Medicine Campus. The sheep were given pain relief and monitored for 24 hours a day over a week for signs of pain or distress before being euthanized so that researchers could examine the structural impact of the catheter on brain tissue.

They found no signs of suffering, tissue damage, or infection following catheter implantation.

Lead author Dr. Riccardo Secoli, also from Imperial's Department of Mechanical Engineering, says, "our analysis showed that we implanted these new catheters safely, without damage, infection, or suffering. If we achieve equally promising results in humans, we hope we may be able to see this platform in the clinic within four years."

"Our findings could have major implications for minimally invasive, robotically delivered brain surgery. We hope it will help to improve the safety and effectiveness of current neurosurgical procedures where precise deployment of treatment and diagnostic systems is required, for instance in the context of localized gene therapy."

Professor Lorenzo Bello, study co-author from the University of Milan, says that "one of the key limitations of current MIS is that if you want to get to a deep-seated site through a burr hole in the skull, you are constrained to a straight-line trajectory. The limitation of the rigid catheter is its accuracy within the shifting tissues of the brain, and the tissue deformation it can cause. We have now found that our steerable catheter can overcome most of these limitations."

More information: Riccardo Secoli et al, Modular robotic platform for precision neurosurgery with a bio-inspired needle: System overview and first in-vivo deployment, *PLOS ONE* (2022). DOI: 10.1371/journal.pone.0275686

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