Nanorobots Could Target Cancers and Clear Blood Clots

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Tiny nano-sized robots and vehicles that can navigate through blood vessels to reach the site of a disease could be used to deliver drugs to tumours that are otherwise difficult to treat.

Once injected or swallowed, most drugs rely upon the movement of body fluids to find their way around the body. It means that some types of disease can be difficult to treat effectively in this way.

One aggressive type of brain tumour known as glioblastoma, for example, kills hundreds of thousands of people a year. But because it produces finger-like projections into a patient's brain tissue that damage the blood vessels around them, it is hard for drugs to reach the tumour site.

'If you inject particles into the body, they will follow the blood,' said Professor Daniel Ahmed, who is currently leading the Acoustic Robotics Systems Lab at ETH Zurich in Switzerland.

Instead, scientists are turning to nanodevices – tiny robots and vehicles – to deliver drugs around the body in a controllable way. But first they have to figure out how to drive them.

Nanoparticles are '10 times smaller than red blood cells and if you use passive particles, there is no way to control them', says Prof. Ahmed.

To overcome this he and his colleagues in the SONOBOTS project are using ultrasound to manipulate nanodevices that carry cancer-killing drugs. Ultrasound technology is typically used by doctors in medical imaging due to the way the high-frequency sound waves bounce

off different parts of the body, which can be used to create an image.

Prof. Ahmed and his fellow scientists have shown, however, that they can guide an air bubble encased within a polymer shell and an imaging chemical - allowing it to be seen - using ultrasound. They call these tiny vehicles nanoswimmers because of their ability to move forward through a liquid. The sound waves push clusters of these nanoswimmers towards the vessel walls. This force, however, is not strong enough to affect the motion of red blood cells in the blood. Prof. Ahmed says he was inspired by how sperm travel: they stick to the vagina’s stationary walls and use them to guide their forward movement. 'We move (the nanoswimmers) to the wall and manipulate them,' he said. This makes it easier to steer the nanoswimmers in the right direction through a blood vessel as they can follow the walls.

Nanoswimmers

This ability to finely control the nanoswimmers is necessary if the scientists want to get their drug-carrying nanovehicles to glioblastomas, which is the ultimate goal. The leaky blood vessels around these tumours mean that the nanoswimmers will have to be carefully navigated to the cancer cells. But once there, researchers can acoustically shake the swimmer so they release their drug payload into the tumour.

So far, the scientists have managed to manipulate and track their nanoswimmers in zebrafish embryos, but Prof. Ahmed said that they are eager to trial their technology in mice. ‘Zebrafish have a tiny brain, but their blood-brain barrier is not mature. We need to move to mice to understand leaky vasculature.’

While there are numerous propulsion mechanisms that could be used to guide drug-carrying nanovehicles, such as chemicals, magnetic fields, or light, ultrasound is attractive for a number of reasons, said Prof. Ahmed. Ultrasound waves can penetrate deeply into the body but have been shown to be safe. It is routinely used to detect foetal heart beats in pregnant women, for example. The technology is also relatively inexpensive and can also be found in the majority of hospitals and clinics.

Precisely delivering drugs to specific locations in the body could help to tackle other common, but deadly diseases.

Professor Salvador Pané and Professor Josep Puigmartí-Luis, researchers in the ANGIE project, hope targeted drug delivery will allow doctors to treat a greater number of stroke patients more effectively. Ischaemic strokes, which occur when blood clots cut off the flow of blood in the brain, are a leading cause of death in the European Union, with more than 1.1 million people suffering strokes each year.

Stroke

The leading form of treatment for patients arriving in hospital after a stroke is with clot-busting drugs, but these are given as an injection and travel around the body before reaching the brain. These drugs also have many side-effects, ranging from nausea and low blood pressure to bleeding in the brain, and not everyone is able to take them.

If treatments could be directed to the location in a vein or artery where a clot is occurring, they could be cleared far more effectively.

'If we concentrate the amount needed at the clot, we will drastically reduce these side effects and we will be able to treat more patients and reduce side effects,' said Prof. Pané, co-director of the Multi-Scale Robotics Lab at ETH Zurich and head of its chemistry laboratory.

In ANGIE the researchers are creating tiny nanorobots that can do just this and deliver the drug directly onto the clot.

Unlike the nanoswimmers in SONOBOTs, the nanorobots being developed under ANGIE are more sophisticated in terms of how they can be controlled.

'The conventional mechanisms for swimming do not work on the nano-scale – if you try to do crawl (swimming stroke) and implement it at a nanoscale, it will not work,' he said. To

overcome this the team are using magnetic fields to control the nano-sized structures, which contain magnetic particles or films.

Prof. Pané likened them to a robotic arm on an industrial assembly line. While industrial robots use a computer-controlled arm to move a gripper at the end around, in the case of the ANGIE nanorobots, the 'arm' is the magnetic field that moves the magnetic nanorobots around. The nanorobots are made from biodegradable tiny iron-based polymer composite structures. Altering the shape and composition of these structures can change how they are controlled.

When the nanorobot reaches its target – a clot in the brain in the case of stroke patients – it then interacts with the clot to deliver its drug payload. Taken in its entirety, ANGIE can be considered a robotic system due to the level of control the magnetic field allows, according to the researchers.

Robots

‘They really are robots – you’re able to control them, accelerate, stop, move them in all three directions,’ said Prof. Puigmartí-Luis, a chemist at the University of Barcelona in Spain. In principle, they can roll, corkscrew, and tumble.

While still in its first year, the ANGIE research team are currently developing the electromagnetic system, which comprises the nanorobots and the infrastructure needed to control these devices. To check that their technology works, they will 3D print a human vascular system, based on real data, and map the optimal path for their nanorobots to reach a clot, Prof. Puigmartí-Luis says.

But if successful, using such nanorobots to deliver drugs to clots in stroke patients, for example, could be achieved with existing equipment in many major hospitals. ‘Magnetic fields are already used in hospitals for magnetic resonance imaging,’ added Prof. Pané.

Although their current aim is to find stroke-causing clots, the technology could be applied to many other diseases, says Prof. Pané. But they need to show that their technology works before they can trial it in people.

Nanodevices offer a promising way of targeting disease treatment, and something that SONOBOTS' Prof. Ahmed thinks will be a reality in the not-too-distant future.

'Initially, when we spoke to medical doctors about the ideas, they thought it was too science-fiction,' but as the study data grows, they are coming around, he said.

Read the original article on Horizon.