Implantable sensors to monitor arterial health

By Andy Tay

High blood pressure is one of the leading causes of death worldwide. Health conditions such as hypertension, high cholesterol and atherosclerosis can induce abnormal blood flow rate and blood pressure, leading to peripheral vascular disease, heart attack and stroke.

The ability to monitor arterial health after a vascular surgery is key to prevent premature deaths from abnormal blood flow and blood pressure. For instance, after a vascular surgery, a doctor might want to know whether blood flow through an operated artery is normal again or whether there are new occlusions in the operated artery. However, most existing devices to monitor arterial health make use of external sensors that cannot capture signals from specific arteries with enough accuracy. Blood flow sensors directly implanted onto arteries could better monitor the health of specific arteries, such as those involved in vascular conditions.

In a recent paper published in *iScience*, a team of researchers led by Professor Zhenan Bao and Dr. Sara Ruth in the Department of Chemical Engineering at Stanford University, and Professor Paige Fox at the Stanford School of Medicine invented an implantable sensor for wireless, battery-free monitoring of arterial blood pressure across a wide range of artery sizes and types.

"Our motivation for this work stemmed from the need for continuous long-term monitoring. We were looking at improving patient outcomes by facilitating early signals of deterioration-whether it is short or long-term progression," says Ruth.

Sensor designs

The team wanted a design that can be wrapped around an artery to detect changes in blood flow. They decided to employ an interdigitated electrode design that can accommodate a greater number of capacitive pressure sensors to improve the sensitivity of their implantable device. This is crucial as the sensor might only be in partial contact with the artery during surgical implantation depending on the size (if artery is too small) and location (if surgical site is too narrow) of the artery.

To ensure biocompatibility of their implantable sensor, the authors also tested different materials, such as polydimethylsiloxane (PDMS) and polyimide, which were found not to induce tissue inflammation. Copper was chosen as the material for the electrodes, electrical interconnect, and wireless antenna as it has high electrical conductivity, biocompatibility, and even possesses anti-inflammatory properties.

***In vitro* testing**

The ability to provide early and timely diagnostics of arterial health before full arterial blockage and adverse symptoms is helpful clinically. Using a continuous flow water pump and an artificial artery made for synthetic cadavers to mimic arteries, the sensor was able to reveal blockages along the artificial artery up to 10 cm upstream and downstream respective of its position. The sensor was also able to reveal the extent of occlusion, although this was slightly more complex as the distance of the partial occlusion from the sensor affected the magnitude of the signal from the sensor, too. Furthermore, with the introduction of a resistor-inductor-capacitor circuit in their sensor, the team was able to wirelessly monitor different occlusion sizes that were upstream or downstream of the sensor for up to 3 days.

Next, the team wrapped their sensor around the femoral artery of a human cadaver (**Figure 1**) and salt water was flowed through the artery using a physiologically relevant pulsatile water pump rate of 60 beats per minute to mimic normal human blood flow pulse rate. The authors showed that their sensor was able to detect for partial and full occlusion. However, as there was no natural blockage in the tested artery, the authors were unable to further verify their sensor performance for occlusion distance and sizes.

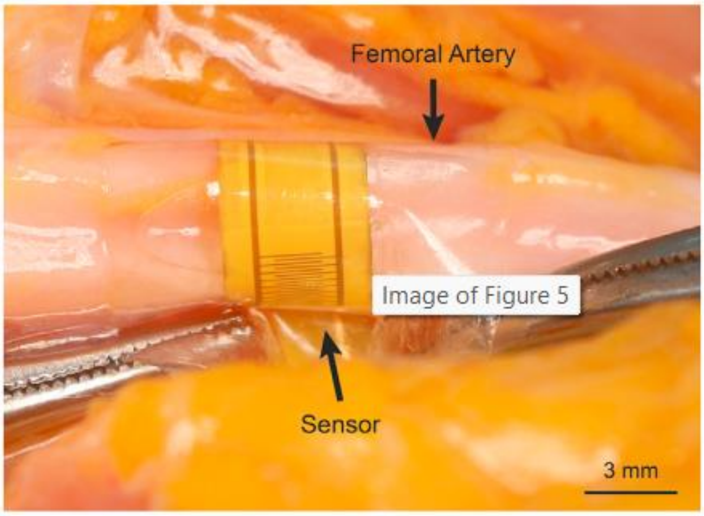

Figure 1 Image showing sensor wrapped around a femoral artery of a human cadaver. Image credit: Ruth, S. R. A., Kim, M. gu, Oda, H., Wang, Z., Khan, Y., Chang, J., Fox, P. M., & Bao, Z. (2021). Post-surgical wireless monitoring of arterial health progression. iScience, 24(9). https://doi.org/10.1016/j.isci.2021.103079

***In vivo* testing**

Using a live rat model, the authors demonstrated that their sensor was able to monitor arterial pulse rate through the skin wirelessly, and the results were compared to gold-standard signals gathered using an external Doppler ultrasound measured through a microphone. The recording was stable for at least two weeks. The team also surgically clamped the rat femoral artery for 15 to 20 seconds to mimic conditions like a blood clot before releasing it. There were observable signal differences during occlusion, but the authors observed that after release, the signal did not return to pre-clamping level, and they hypothesized that the viscoelasticity of the artery might impede it from immediately returning to its original state.

“One of the exciting parts about this technology is that it works together with current surgical work streams in that it does not require additional procedures. We hope this will be a springboard for researchers to think about these issues and how we can improve healthcare within the current hospital framework so that it can be smoothly adopted. More specific to this work, it would be great to see this sensor further developed to help us reach the vision of long term continuous monitoring of arterial health,” says Ruth.

Boost arterial health with implantable sensor

In this paper, Ruth and colleagues demonstrated the potential of a wireless, implantable sensor to monitor arterial health. There is huge potential to employ such devices for long-term clinical monitoring of arterial health in vulnerable patients such as persons who have undergone vascular surgery and are susceptible to recurring vascular conditions. Data from the sensor may even be paired with a warning system to alert users in a timely manner of impending stroke.

Source article

Ruth, S. R. A., Kim, M. gu, Oda, H., Wang, Z., Khan, Y., Chang, J., Fox, P. M., & Bao, Z. (2021). Post-surgical wireless monitoring of arterial health progression. *IScience*, *24*(9). https://doi.org/10.1016/j.isci.2021.103079

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