New surgical tools with smart sensors can advance cardiac surgery and therapy
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Researchers developed a new class of medical instruments equipped with an advanced soft electronics system that could dramatically improve the diagnoses and treatments of a number of cardiac diseases and conditions.

Detailed in a new paper published in the journal *Nature Biomedical Engineering*, the researchers, led by engineers at the George Washington University and Northwestern University, applied stretchable and flexible matrices of electrode sensors and actuators, along with temperature and pressure sensors, to a balloon catheter system, often used in minimally invasive surgeries or ablations to treat conditions such as heart arrhythmias.

The new system, which conforms better to the body's soft tissue than current devices, can perform a variety of functions, including: simultaneous in vivo measurements of temperature, force of contact and electrophysiological parameters; the ability to customize diagnostic and therapeutic functions; and real-time feedback. The new system can also dramatically reduce the length of invasive ablation procedures and exposure of patients and doctors to X-ray radiation.

**The situation**

Many minimally invasive surgeries rely on catheters inserted into the body through small incisions to conduct diagnostic measurements and therapeutic interventions. Physicians, for example, use this catheter-based approach to map and treat irregular heartbeats, or arrhythmias, often by locating and killing or ablating cardiac tissue area which is causing the arrhythmias.

Though widely used in surgery, the current catheter-based approach has a number of drawbacks. The rigidity of today's catheter devices means they do not conform well to soft, biological tissues, impacting high fidelity mapping of an organ's electrophysiological signals. Current devices make contact with only a small part of an organ at a time, making it necessary to constantly move a probe around, lengthening medical procedures. Current catheter systems are also limited in the number of functions they can perform, requiring physicians to use multiple catheters in a single ablation procedure.

Additionally, long procedures—for example, to locate and ablate tissues causing arrhythmias—risk
exposing both patient and physician to potentially
damaging X-rays, as physicians rely on X-ray
images during the course of the surgery to guide
their catheters.

The benefit

The new class of instruments the researchers
developed will allow physicians to acquire a rich set
of electrophysiological information and to complete
surgeries in shorter times with a single
instrumented catheter system.

By outfitting a balloon catheter with advanced
organ conformal electronic components, sensors
and actuators, the researchers overcame the flaws
of current systems. Specific advances over
previous systems include:

- Instrumented sensors and actuators in
  multiplexed array formats can probe the
  complex nature of tissues, specifically in the
  beating heart. This will allow, for example,
  for better localization of sources of lethal
  arrhythmias causing sudden cardiac death.
- The device’s multilayered and
  multifunctional architecture with combined
  diagnostic and therapeutic functions
  enhances a number of minimally invasive
  cardiac procedures, including radio
  frequency or irreversible electroporation
  ablation—wherein cardiac or nerve cells are
  ablated, or "burned," to eliminate sources of
  arrhythmia—and the delivery of drugs and
  other biomaterials directly into cells through
  a process called reversible electroporation.
- Capabilities for real-time feedback control,
  enabled by simultaneous, multimodal
  operation of sensors and actuators.

"We have taken new breakthrough materials and
fabrication techniques typically employed by the
semiconductor industry and applied them to the
medical field, in this case cardiology, to advance a
new class of medical instruments that will improve
cardiac outcomes for patients and allow physicians
to deliver better, safer and more patient-specific
care," says Igor Efimov, the Alisann and Terry
Collins Professor of Biomedical Engineering at the
George Washington University.

"Hard, rigid catheters cannot conform to the heart
because the heart itself is not hard and rigid. We
leveraged our advances in soft, stretchable and
flexible electronics to develop medical devices that
include elastic, interconnected arrays of sensors
and actuators, capable of gently and softly
conforming to tissue surfaces. The result improves
the accuracy and precision of associated surgical
processes, for faster, less risky and more effective
treatments," says John A. Rogers, the Louis A.
Simpson and Kimberly Querrey Professor of
Materials Science and Engineering, Biomedical
Engineering and Neurological Surgery at
Northwestern University.

More information: Catheter-integrated soft
multilayer electronic arrays for multiplexed sensing
and actuation during cardiac surgery, Nature
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