Researchers get straight to the heart of piezoelectric tissues

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For years, scientists have wondered whether the heart and adjacent vessels might have evolved to be piezoelectric, meaning that the tissue can generate an electrical charge when squeezed. They thought that perhaps the heart takes advantage of this electromechanical relationship to power decades of continuous beating. While some studies have supported the idea that the walls of the aorta are piezoelectric or even ferroelectric, where permanent electric dipoles can be switched by an electric field, the most recent research finds no evidence of these properties.

A collaboration of German researchers investigated the question by testing samples of pig aorta using a traditional setup, known as Sawyer-Tower, to detect ferroelectricity. Their experiments suggest that the aorta has no special properties, and instead acts as a standard dielectric material that does not conduct current. They report these findings this week in *Applied Physics Letters*.

Scientists first realized that biological tissues can be piezoelectric in the 1950s, when Japanese scientists Eiichi Fukada and Iwao Yasuda detected this property in bone tissue. By the late 1800s, scientists knew that bones strengthen themselves in response to applied stress, but later research showed that bone compression generates an electrical charge, which stimulates biological processes to strengthen bone tissue. Since then, scientists have detected piezoelectricity in other tissues, including the trachea, intestines, muscle fibers and even lobster shells.

Recent studies using a technique called piezoresponse force microscopy (PFM) offered evidence that pig aortas are not only piezoelectric but also ferroelectric, which is a prerequisite for piezoelectricity in disordered materials. PFM is a powerful technique for detecting piezoelectricity and ferroelectric switching, but can only address micrometer-sized areas. Moreover, in tests of ferroelectricity, the technique can create misleading artifacts.

"There was a lot of controversy on this topic," said Thomas Lenz of the Max Planck Institute for Polymer Research and one of the authors of the study. He and colleagues weighed in on the discussion using a simple Sawyer-Tower setup, first used by C.B. Sawyer and C.H. Tower to measure ferroelectric hysteresis loops in 1929.

The Sawyer-Tower technique involves applying an electric field to a material and then measuring the resulting electric displacement. Coupled with a photonic sensor, researchers can simultaneously measure how the material changes shape in response to the current. Unlike PFM, the technique provides quantitative results on large-scale electromechanical properties.

The researchers worked with biologists and anesthesiologists from the University Medical Center Mainz, in Germany, to obtain pig aortas. They preserved aorta pieces in the same way as did the previous studies using PFM. They found that when they applied an electric field over a centimeter-sized piece of the tissue, it changed shape like any dielectric material showing electrostriction.

If the heart or other tissues were ferroelectric and piezoelectric, then they would need to be made up of a biopolymer with a polar crystal structure. For the aorta, this is extremely unlikely because its walls have a complex anatomical structure that is unlike bones, where the polar structure of collagen yields their fascinating piezoelectric properties.

"We could not see any sign of piezoelectricity or ferroelectricity, and we thought we should contribute that to the scientific discussion," said Lenz, noting that their work is just one line of evidence on this topic. "It's a pity. I would have liked to study it further."

More information: Thomas Lenz et al, Ferroelectricity and piezoelectricity in soft biological tissue: Porcine aortic walls revisited, *Applied Physics Letters* (2017). DOI: 10.1063/1.4998228

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