Instead of defibrillator's painful jolt, there may be a gentler way to prevent sudden death

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Each year in the United States, more than 200,000 people have a cardiac defibrillator implanted in their chest to deliver a high-voltage shock to prevent sudden cardiac death from a life-threatening arrhythmia. While it's a necessary and effective preventive therapy, those who've experienced a defibrillator shock say it's painful, and some studies suggest that the shock can damage heart muscle.

Scientists at Johns Hopkins believe they have found a kinder and gentler way to halt the rapid and potentially fatal irregular heart beat known as ventricular fibrillation. In a study published in the September 28 issue of *Science Translational Medicine*, they report success using lower amplitude, high-frequency alternating current at 100-200 Hz to stop the arrhythmia in the laboratory. They say this approach also may prove to be less painful for patients because of the lower amplitude and different frequency range than what is used for standard defibrillator shocks.

"We believe we have found a way to stop a life-threatening arrhythmia by applying a high-frequency alternating current for about one-third of a second," says Ronald Berger, M.D., Ph.D., a cardiac electrophysiologist at the Johns Hopkins Heart and Vascular Institute and a professor of medicine and biomedical engineering at the Johns Hopkins University School of Medicine. "The alternating current puts the disorganized, rapidly moving heart cells in a refractory state, like suspended animation. When we turn off the current, the cells immediately return to a normal state. If further research confirms what we have learned so far, this could be less painful for a patient while achieving the same result,"

says Berger, who is the senior author of the study.

Graduate student Seth Weinberg, a co-lead author of the study, says the way heart cells behave during ventricular fibrillation is like having a football stadium full of fans, all of whom are doing "the wave" in an uncoordinated, disorganized fashion. "Applying the alternating current," he says, "is like freezing all of the fans in a position halfway between sitting and standing. When the current is turned off, the fans sit down in an orderly way, ready to be instructed to do the wave in a coordinated way."

Berger says he and his colleagues, a team of Johns Hopkins cardiologists and biomedical engineers, have shown a proof of principle and a novel scientific finding: It's the first time heart cells have been put in a suspended state to interrupt ventricular fibrillation.

"The idea to put heart cells in a brief state of suspended animation came from studies showing that alternating current could be used to put nerve cells in a similar state to block the signals that cause pain," says Harikrishna Tandri, M.D., assistant professor of medicine and the other co-lead author of the study.

To ensure that they were correctly assessing the response of the heart cells to the high frequency current, and, at the same time, distinguishing the response from the cells' native electrical activity, the researchers used a technique called optical mapping. Unlike other electrical recording techniques, optical mapping measurements are not affected by applied electrical stimuli, according to co-author Leslie Tung, Ph.D., professor of biomedical engineering, who led the optical mapping aspect of the research.

In order to allow the team to explore the response of individual heart cells to the high-frequency electrical current, co-author Natalia

Trayanova, Ph.D., professor of biomedical engineering, produced a multi-scale computational model of the heart.

While more testing is needed in animal models, the researchers are optimistic that their work may lead to a new approach to shock the human heart back to a normal rhythm. "We are ultimately hoping to develop a device that, instead of delivering a painful, high-voltage shock when it detects a life-threating arrhythmia, applies a more gentle alternating current for the right amount of time to stop the dangerous rhythm. We think that would be a great benefit to the millions of people worldwide who have a defibrillator to prevent sudden death," Berger says.

Ventricular fibrillation is an uncontrolled twitching or quivering of muscle fibers in the lower chambers of the heart. It is the most dangerous type of arrhythmia and is often caused by a heart attack. During ventricular fibrillation, the heart cannot pump blood to the rest of the body, which leads to sudden death unless the person is revived through CPR or a shock from an external defibrillator. People who are fortunate to have survived ventricular fibrillation and those who have other risk factors, are advised to have an implanted defibrillator to detect ventricular fibrillation and shock the heart back to a normal rhythm.

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