A novel, low-energy defibrillation method shows promise to reduce pain and tissue damage for millions who suffer heart arrhythmias.
Like a big kick in the chest—that’s how people who have undergone defibrillation while conscious often describe it. Applied externally with “paddles” or by implantable devices, defibrillation applies a brief burst of electrical current at energy levels many times higher than the human pain threshold.

“It’s a huge shock, 130 to 360 joules externally, about seven internally,” says computational scientist Elizabeth Cherry of the Rochester Institute of Technology (RIT, formerly at Cornell). “Basically, conventional defibrillation is for emergencies, most often ventricular fibrillation (VF), which is almost always life-threatening and requires immediate resuscitation,” says Cherry, whose work focuses on the heart’s complex electrophysiology.

Many other cardiac arrhythmias, however, especially atrial fibrillation (AF)—affecting about 2.2 million Americans—may present serious health problems that can be treated with defibrillation…if it didn’t involve serious pain and risk of lasting tissue damage.

“The idea of Far-Field Antifibrillation Pacing, or FFAP,” explains Cherry, “is that you apply a pulsed electric field, and as it encounters discontinuities, such as blood vessels, collagen and other things, it recruits these discontinuities as virtual electrodes. In this way, many new activations develop simultaneously throughout the heart, which synchronize electrical activity and restores normal rhythm.”

Toward that end, in studies involving both laboratory experiments and computational simulation, Cherry and a large group of collaborators, including physicists Flavio Fenton (Cornell), Jean Bragard (University of Navarra, Spain), and others at Cornell and the Max Planck Institute (Göttingen, Germany), conducted a research program that combines clinical, experimental, and theoretical perspectives with computer simulation. Because of the great range of scales involved in heart anatomy—both spatially (from a single cell to the full-size heart) and over time (microseconds to minutes)—their modeling requires large amounts of computing. For their whole-organ model of cardiac electrical dynamics, they relied on PSC’s BigBen (up to 500 processors simultaneously) until it was decommissioned this year, and are now moving their code to Purdue’s Steele system, both TeraGrid resources.

The FFAP studies focused on AF, an arrhythmia in the heart’s upper chambers. AF often arises with age and, unlike VF, can persist for years. Although AF seldom requires emergency treatment, it increases risk for stroke and heart failure. Current treatments, primarily anti-arrhythmic drugs and sedated defibrillation in a clinical setting (called cardioversion), aren’t especially effective and often have side effects. “There’s a big clinical hole,” says Cherry, “in how to treat this type of disease.”

Their heart experiments with FFAP have shown a success rate comparable to conventional defibrillation, higher than 90 percent, in stopping AF and restoring a normal heartbeat. Their computational simulations correlated with these experiments confirm the theory underlying FFAP and make it possible to test many possible remedies. Cherry and her team reported their findings last year in Circulation (August 2009), and newer publications are in press.

“Based on pain threshold values in the literature,” says Cherry, “we believe our approach is currently at the threshold and that with optimization of parameters such as shock waveform and electrode placement, guided by computer simulation, we’ll be below it.”

For more information:
http://thevirtualheart.org/FentonCherry/cherry.html
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