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The Physics of Cardiac Fibrillation: Strings that kill[1]

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Fibrillation is a state of spatio-temporal chaos in a 3d-biological excitable medium, namely the heart muscle. The building blocks are wave-emitting three-dimensional topological singularities in the electric excitation field of the tissue. These string like singularities send out a rotating wave fields with very fast frequencies (up to 10 times normal heart rate) and thus dominate over the pacemaker. The incoherent electrical excitation of the spatio-temporal chaotic dynamics leads to an unsynchronized contraction of the cardiac muscle and to the loss of the pumping action, and if untreated to death. Due to the topological nature of the spatio-temporal chaotic state it is very difficult to control. Current defibrillation technologies use strong electric field pulses (1 kV, 30 A, 12 ms) to reset the whole muscle. Here we report that natural muscle heterogeneities act as wave emitting sites when a weak electric field pulse is applied across the tissue. We report theoretical predictions on the physics and support the findings by results from experiment. This work was conducted in collaboration with Stefan Luther (MPIDS), Falvio Fenton (Cornell), Amgad Squires (Cornell), Robert Gilmour (Cornell), Valentin Krinsky (MPIDS), Alain Pumir (NIce).

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