Cardiac Death: A Dynamical Disease Model

Ventricular fibrillation is the leading immediate cause of death in the industrialized world. That fibrillation/defibrillation is still not quantitatively understood is attested by egregious disasters in recent clinical experience with antiarrhythmic drugs. We present a heuristic dynamical model of possible routes to cardiac death. The model describes the normal healthy myocardium as a bistable nonlinear dynamical system in which, counter-intuitively, a strange attractor represents normal sinus rhythm and a limit cycle attractor represents ventricular fibrillation. These attractors co-exist over a range of values of a control parameter. Ventricular fibrillation may arise in the healthy heart from initial conditions lying within the limit cycle basin or from the control parameter(s) changing in the onset and progression of aging and disease thereby inducing a collision of the strange attractor with the basin boundary. The strange attractor is annihilated (a A*blue sky catastrophe*@); the limit cycle remains. The resultant ventricular fibrillation evolves to cardiac death via either of two discontinuous bifurcations of the limit cycle: an infinite period bifurcation in which the limit cycle is annihilated (another A*blue sky catastrophe*@), or a subcritical Hopf bifurcation of the limit cycle to a stable focus (a A*black hole*@). Both routes end in the time-independent state, cardiac death. Our model is qualitative. As is characteristic of dynamical models, ours does not provide quantitative predictions of events, but rather something of perhaps equal value: an insight into the process generating them.