Supplementary Material

Reentry via high-frequency pacing in a mathematical model for human-ventricular cardiac tissue with a localized fibrotic region

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Figure S1: Spiral wave. (a) Pseudocolour plot of $V_m$ illustrating a spiral wave. The white squares indicate the points from where we record the time series of $V_m$. (b) Time series of $V_m$ from one of these representative points. (c) The averaged power spectrum of these time series; this is the average of the power spectra of the time series from the four representative points mentioned above. The spiral-wave frequency $\omega$ is the value of the frequency of the dominant peak in this spectrum, i.e., the peak at 6.4 Hz.

- 14.94s
- 15.276s
- 16.2s

Figure S2: Wave distortion (WD). Pseudocolor plots of the transmembrane potential showing WD in a medium with a fibroblast clump of radius $r=1$ cm. The size of the domain is $640 \times 640$ grid points, with a spatial resolution $\delta x = 0.006$ cm and a temporal resolution $\delta t = 0.003$ ms.
Figure S3: Wave distortion in a medium with fibroblast clump of with a random fibroblast distribution that leads to a nonuniform mean density. Top-panel: the distribution of fibroblasts in the clump. The percentage $p_f$ of fibroblasts is 35%, within a radius of 1 cm; and then it decreases linearly to zero (in the normal region), within an annular region with width of 0.4 cm. Bottom-panels: pseudocolor plots of $V_m$ showing the formation of WDs in the medium with this distribution of fibroblasts.

Figure S4: Wave distortion (WD) in an active-fibroblast model. Pseudocolor plots of $V_m$ showing the formation of wave distortions around a fibroblast clump; here, we use the active-fibroblast model due to MacCanell, et al.,[42]
1 Model of fibroblast clump with remodelling in gap-junctional coupling and four ionic currents

We divide the medium into three regions (see fig. S5), namely, the normal region, the border zone (BZ), and the central zone (CZ); CZ lies inside the fibroblast clump; the BZ region is the region between CZ and the normal region. In the BZ region we reduce the conductances of $I_{Na}$ by 50%, $I_{CaL}$ by 50%, $I_{Kr}$ and $I_{Ks}$ by 30%. In the CZ region we reduce the conductances of $I_{Na}$ by 70%, $I_{CaL}$ by 70%, $I_{Kr}$ and $I_{Ks}$ by 60%. Furthermore, the value of the diffusion coupling is linearly reduced from its control value in the normal region to 60% of its original value in the CZ region.

Figure S5: Wave distortion (WD) around a fibroblast clump of $r = 1 \text{ cm}$ and $p_f = 30\%$ with electrophysiological remodelling. Top-panel: the normal region (blue), the BZ border zone (light green), and the CZ central zone (brown). Bottom-panel: pseudocolour plots of $V_m$ showing the occurrence of WDs at $t= 1.02 \text{ s}$ (this is much earlier than the WD-initiation time $\tau = 15.4 \text{ s}$ without electrical remodelling).

Video captions

Video S1: Wave distortions around a fibroblast clump via high-frequency PP protocol. Video showing the formation of wave distortions and spiral waves around a fibroblast clump of $p_f = 30\%$ and radius $R = 1 \text{ cm}$. For this video, we use 10 frames per second with each frame separated from the succeeding frame by 20ms in real time.
Video S2: Absence of wave distortions around the fibroblast clump at low-frequency PP protocol. Video showing that no wave distortions occur around a fibroblast clump of $p_f = 30\%$ and radius $R = 1$ cm if we use low-frequency PP protocol. For this video, we use 10 frames per second with each frame separated from the succeeding frame by 20ms in real time.

Video S3: Delayed occurrence of wave distortions around the fibroblast clump with higher excitability. Video showing that the formation of wave distortions around a fibroblast clump is delayed if we increase the excitability inside the clump and around it by increasing the conductance of $I_{Na} (G_{Na})$ by 1.1 times. The wave distortion occur at 17.7s, which is higher than the averaged value of 15.4 s in the case of normal excitability. For this video, we use 10 frames per second with each frame separated from the succeeding frame by 20ms in real time.

Video S4: Re-entry via the TP protocol. Video showing the initiation of reentry, because of our high-frequency pacing (TP protocol), in a medium with a fibroblast clump with $R=2.4$ cm and $p_f=33\%$ (left panel) and 43\% (right panel). For this video, we use 10 frames per second with each frame separated from the succeeding frame by 20ms in real time.

Video S5: TP-pacing induced reentry in our 3D simulations with a cylindrical fibroblast clump. Video showing the formation of reentry, via our TP stimulation protocol with PCL= 152 ms, in a 3D domain with a cylindrical fibroblast clump, $p_f = 65\%$, and $R=2.4$ cm. For this video, we use 10 frames per second with each frame separated from the succeeding frame by 20ms in real time.