

Persistence, Co-existence and Mobility of Epicardial Rotors During Human Ventricular Fibrillation

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Introduction

The mechanisms that sustain ventricular fibrillation (VF) remain controversial.

Experimental studies of VF in animal hearts have shown that VF can be sustained by multiple re-entrant sources [1] or a single persistent re-entrant source [2], whilst other studies have shown a low incidence of epicardial re-entry [3].

The aim of this study was to determine the persistence, coexistence and mobility of epicardial rotors during VF in the human heart by mapping the entire ventricular epicardial surface.

Methods

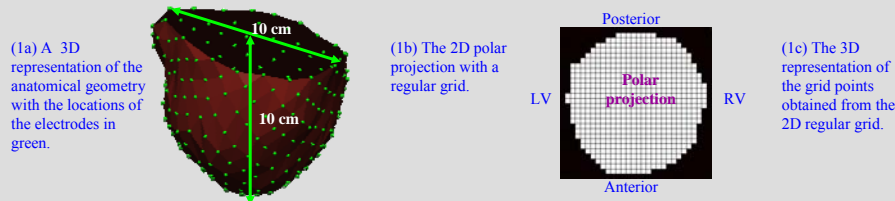
Data acquisition: In 10 patients undergoing cardiac surgery, VF was induced by burst pacing, and a 20-40 s episode of fibrillatory activity was sampled at 1 kHz over the whole ventricular epicardium using a sock containing 256 unipolar contact electrodes connected to a UnEmap system [4,5].

Selection of electrograms: A proportion of the signals had poor signal-to-noise ratios. Using frequency analysis, we rejected signals with dominant frequency < 1.5 Hz or > 45 Hz.

Geometry: (Fig. 1a) The 3D locations of the electrodes were projected onto (Fig. 1b) a circular 2D polar plot. Signals were linearly interpolated from the electrodes onto a fine regular grid (100x100 pixels).

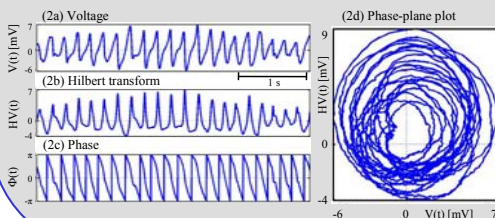


The epicardial sock during surgery



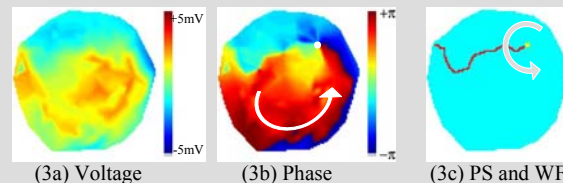
Activation times were computed at the minimum negative slope of voltage [6]. We subsequently applied a signal de-trending algorithm [7] in order to set the voltages at the activation times to be zero.

Phase was computed from the phase-plane plot (Fig. 2) using the Hilbert transform [8] for each de-trended signal, and phase maps were plotted using the 2D polar plot (Fig. 3b).

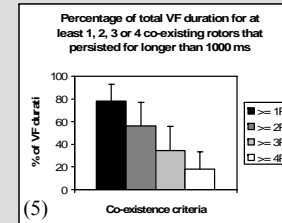
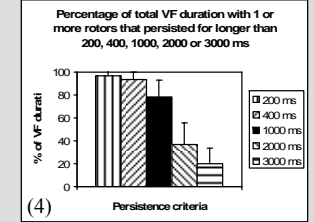


Phase singularities (PS) are the tips of re-entrant waves on the epicardial surface (epicardial rotors). PS were identified using a method based on the topological charge [9]. Chirality is indicated by yellow dots (anticlockwise) and dark blue dots (clockwise) on the 2D polar maps (Fig. 3c). Rotor trajectories were tracked using an algorithm that allowed PS to move up to 15 mm between time-frames, whilst connecting PS that disappeared for < 100 ms (~ half cycle).

Activation wavefronts (WF) correspond to spatial isochrones of activation time. Due to signal de-trending, WF can equivalently be determined from the isolines of zero phase under the Hilbert transform. WF were identified using an active edge method [7] and illustrated as red lines on the 2D polar maps (Fig. 3c).

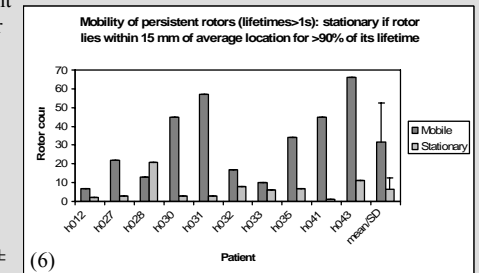


Persistence: Epicardial rotors with lifetimes greater than 400 ms were present for more than 90% of the total VF duration (Fig. 4). When the lifetime threshold was increased to 1000, 2000, and 3000 ms, at least one persistent rotor was present for more than 78%, 34% and 20%, respectively, of the total VF duration.



Co-existence: When defining persistent rotors as those with lifetimes greater than 1000 ms (approximately 5 rotations), we found that 2 or more persistent rotors were present for 55% of the total VF duration, and 3 or more persistent rotors were present for 32% of the time (Fig. 5).

Mobility: The temporal mean location was determined over the lifetime of each persistent rotor (i.e. with lifetime > 1000 ms). The rotor was classified as stationary if its core remained within 15 mm of the mean location for more than 90% of its lifetime (otherwise mobile). Using these criteria, the numbers of mobile and stationary rotors varied from patient-to-patient (Fig. 6). In all but one patient, there were more mobile than stationary persistent rotors. Over all patients, the mean ± SD number of mobile rotors (32 ± 21) was significantly greater than that for stationary rotors (7 ± 6, P<0.01).



Summary

Human VF is characterised by a small number of persistent mobile epicardial rotors, together with a large number of short-lived epicardial PS.

This finding has implications for understanding the mechanisms that sustain VF in the human heart, and thus for treatment of this condition.

References

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Results

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